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(54) **INTELLIGENT AND AUTOMATIC REPLICATION LOAD SCORE BASED LOAD BALANCING AND RESILIENCY OF REPLICATION APPLIANCES**

(71) Applicant: **Veritas Technologies LLC**, Santa Clara, CA (US)

(72) Inventors: **Pramila Dhaka**, Pune (IN); **Parikshit Hooda**, Rohtak (IN)

(73) Assignee: **Veritas Technologies LLC**, Santa Clara, CA (US)

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G06F 11/10	(2006.01)
G06F 9/50	(2006.01)
G06F 3/06	(2006.01)

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CPC ***G06F 9/5083*** (2013.01); ***G06F 3/065*** (2013.01); ***G06F 3/067*** (2013.01); ***G06F 3/0619*** (2013.01); ***G06F 9/45558*** (2013.01); ***G06F 9/4868*** (2013.01); ***G06F 9/505*** (2013.01); ***G06F 11/1448*** (2013.01); ***G06F 11/1458*** (2013.01); ***G06F 11/1469*** (2013.01); ***G06F 11/1492*** (2013.01); ***G06F 16/184*** (2019.01); ***G06F 16/1844*** (2019.01); ***G06F 16/27*** (2019.01); ***G06Q 10/06*** (2013.01); ***H04L 67/1095*** (2013.01); *G06F 2009/4557* (2013.01); *G06F 2009/45595* (2013.01)

(58) **Field of Classification Search**
CPC G06F 9/5083; G06F 9/505; G06F 9/45558; G06F 3/067; G06F 3/065; G06F 16/27; G06F 11/448; G06F 11/458; G06F 11/469; G06F 11/1471; G06F 11/1484; G06F 3/0689; G06F 16/184; G06F 16/1844; G06F 16/2358; G06F 9/4868; G06F 11/1492; G06F 11/1458; G06F 11/1469; G06F 11/1448; G06F 11/2056; H04L 67/1095; G06Q 10/06
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,557,079	B1 *	4/2003	Mason, Jr.	G06F 12/0862 711/113
9,514,180	B1 *	12/2016	Cadarette	G06F 16/2358

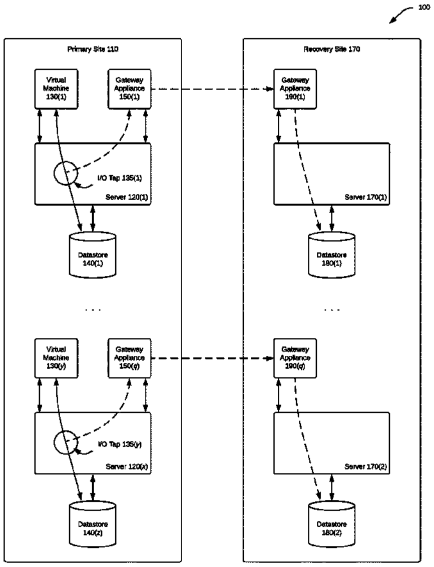
(Continued)

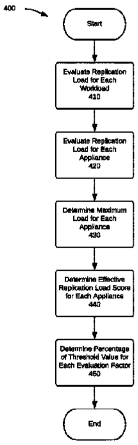
Primary Examiner — Srirama Channavajjala
(74) *Attorney, Agent, or Firm* — Campbell Stephenson LLP

(57) **ABSTRACT**

Various systems and methods are provided for receiving replication data at a recovery site from a replication process initiated on a primary site, where the recovery site includes at least a first gateway appliance and a second gateway appliance that can be used to process the replication data. The systems and methods further involve evaluating a replication load of the first gateway appliance, which includes analyzing at least a first evaluation factor and a second evaluation factor related to the replication process, and in response to evaluating the evaluation factors, determining whether the first gateway appliance is overloaded. In response to determining that the first gateway appliance is overloaded, rebalancing a replication workload between the first gateway appliance and the second gateway appliance.

17 Claims, 9 Drawing Sheets




400
Start
Evaluate Replication Load for Each Workload 410
Evaluate Replication Load for Each Appliance 420
Determine Maximum Load for Each Appliance 430
Determine Effective Replication Load Score for Each Appliance 440
Determine Percentage of Threshold Value for Each Evaluation Factor 450
End

(51) **Int. Cl.**

G06F 9/455	(2018.01)
G06F 16/27	(2019.01)
G06F 16/182	(2019.01)
G06F 11/14	(2006.01)
H04L 29/08	(2006.01)
G06F 9/48	(2006.01)
G06Q 10/06	(2012.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0185973	A1*	8/2007	Wayda	G06F 3/065 709/217
2011/0099146	A1*	4/2011	McAlister	G06F 11/2069 707/634
2012/0233123	A1*	9/2012	Shisheng	G06F 11/004 707/639
2012/0259968	A1*	10/2012	Anaya	G06F 9/505 709/224
2012/0303791	A1*	11/2012	Calder	G06F 9/5083 709/224
2014/0033201	A1*	1/2014	Dawkins	G06F 11/2069 718/1
2014/0040206	A1*	2/2014	Ramakrishnan	G06F 11/2097 707/640
2014/0351644	A1*	11/2014	Garg	G06F 11/26 714/32
2014/0372800	A1*	12/2014	Garza	G06F 11/2097 714/20
2016/0026535	A1*	1/2016	Bhat	G06F 11/2097 714/19
2016/0239396	A1*	8/2016	Deng	G06F 11/1666
2017/0351591	A1*	12/2017	Crawford	G06F 11/3485

* cited by examiner

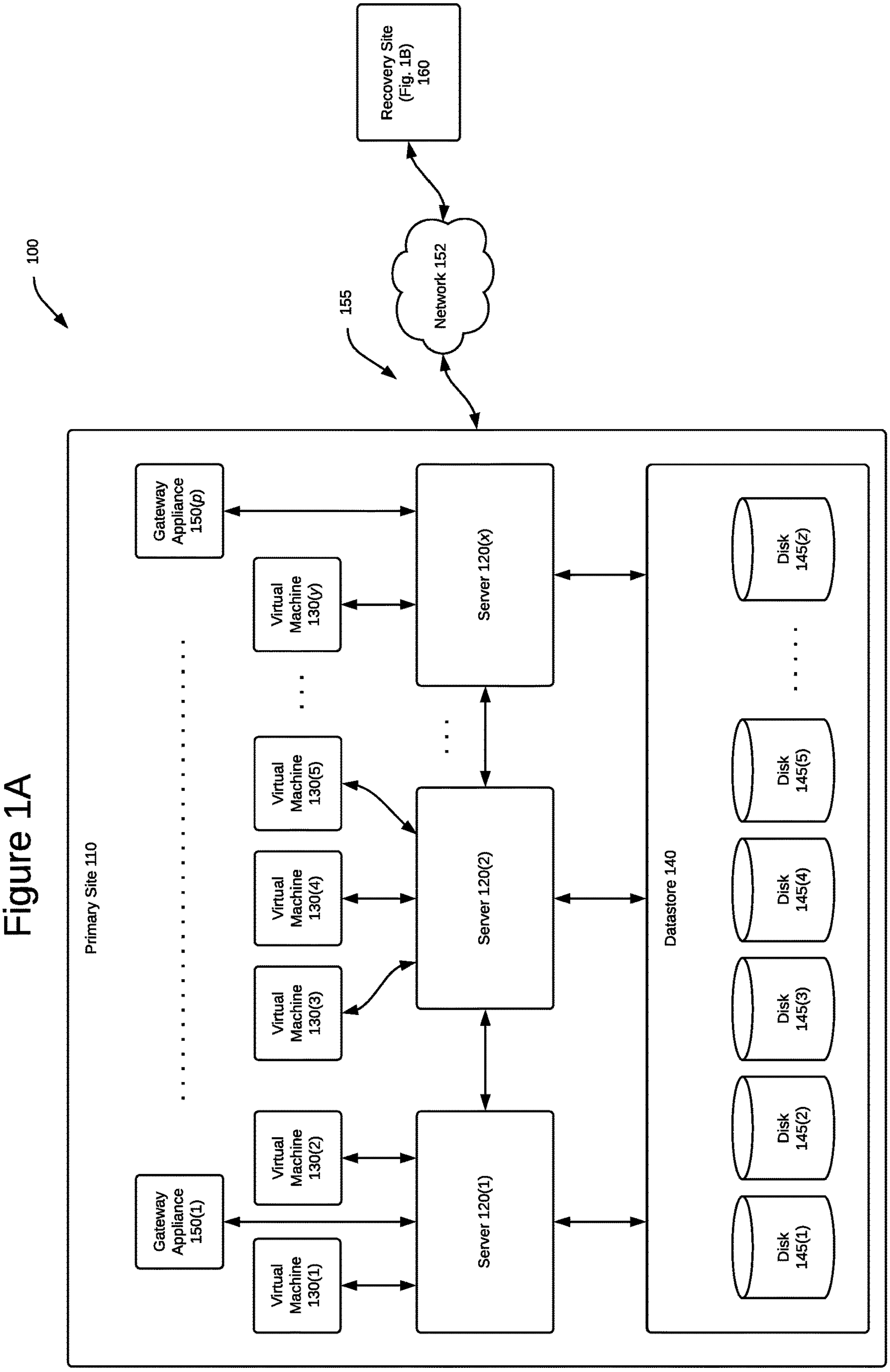

100
155
Recovery Site
(Fig. 1B)
160
Network 152
Primary Site 110
Gateway Appliance 150(*p*)
Virtual Machine 130(*y*)
Server 120(*x*)
Disk 145(*z*)
Virtual Machine 130(5)
Virtual Machine 130(4)
Virtual Machine 130(3)
Server 120(2)
Datastore 140
Disk 145(5)
Disk 145(4)
Disk 145(3)
Gateway Appliance 150(1)
Virtual Machine 130(2)
Virtual Machine 130(1)
Server 120(1)
Disk 145(2)
Disk 145(1)

Figure 1A

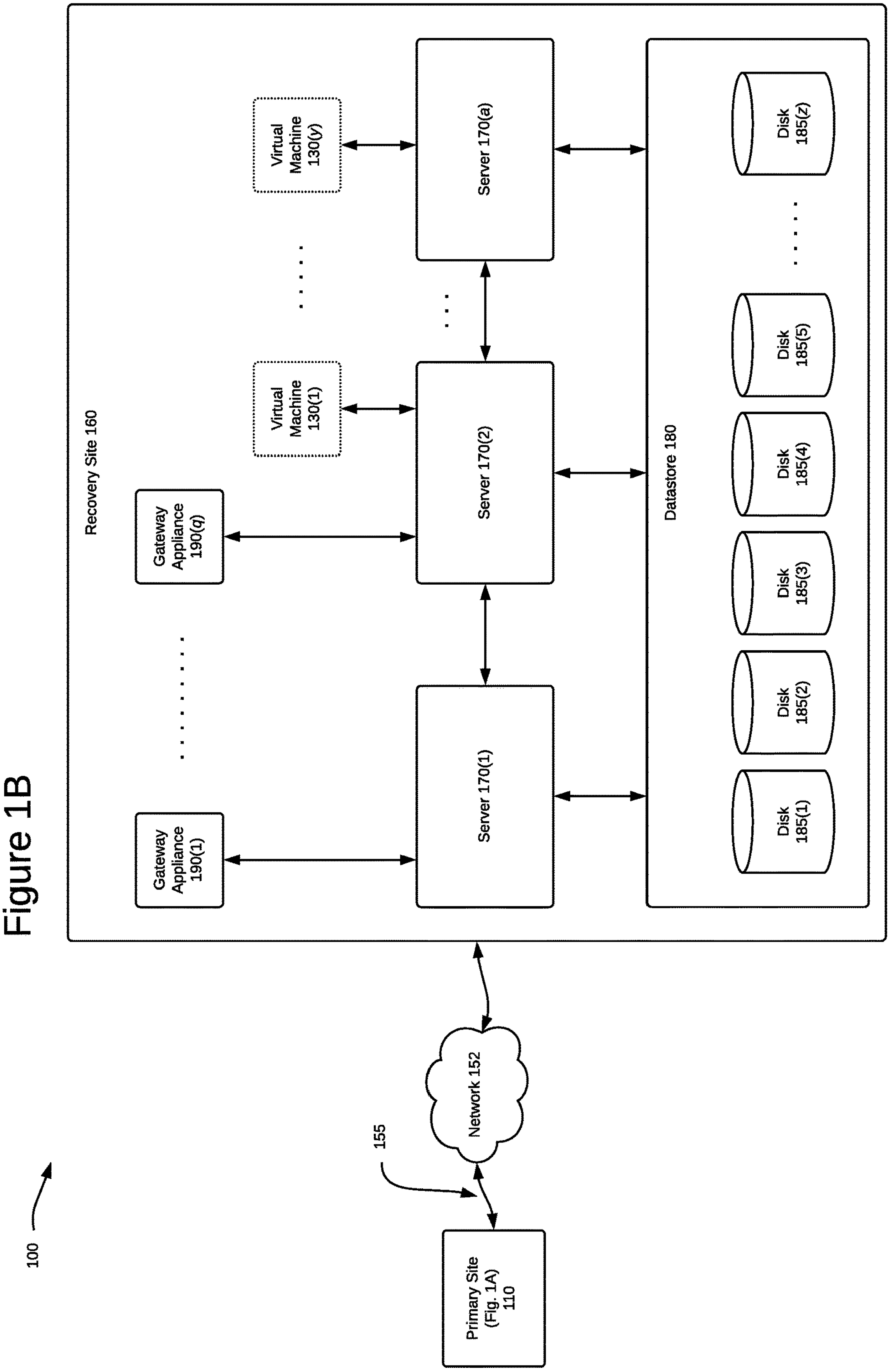

100
Primary Site
(Fig. 1A)
110
155
Network 152
Recovery Site 160
Gateway
Appliance
190(1)
Gateway
Appliance
190(*q*)
Virtual
Machine
130(1)
Virtual
Machine
130(*y*)
Server 170(1)
Server 170(2)
Server 170(*a*)
Datastore 180
Disk
185(1)
Disk
185(2)
Disk
185(3)
Disk
185(4)
Disk
185(5)
Disk
185(*z*)

Figure 1B

Figure 1C

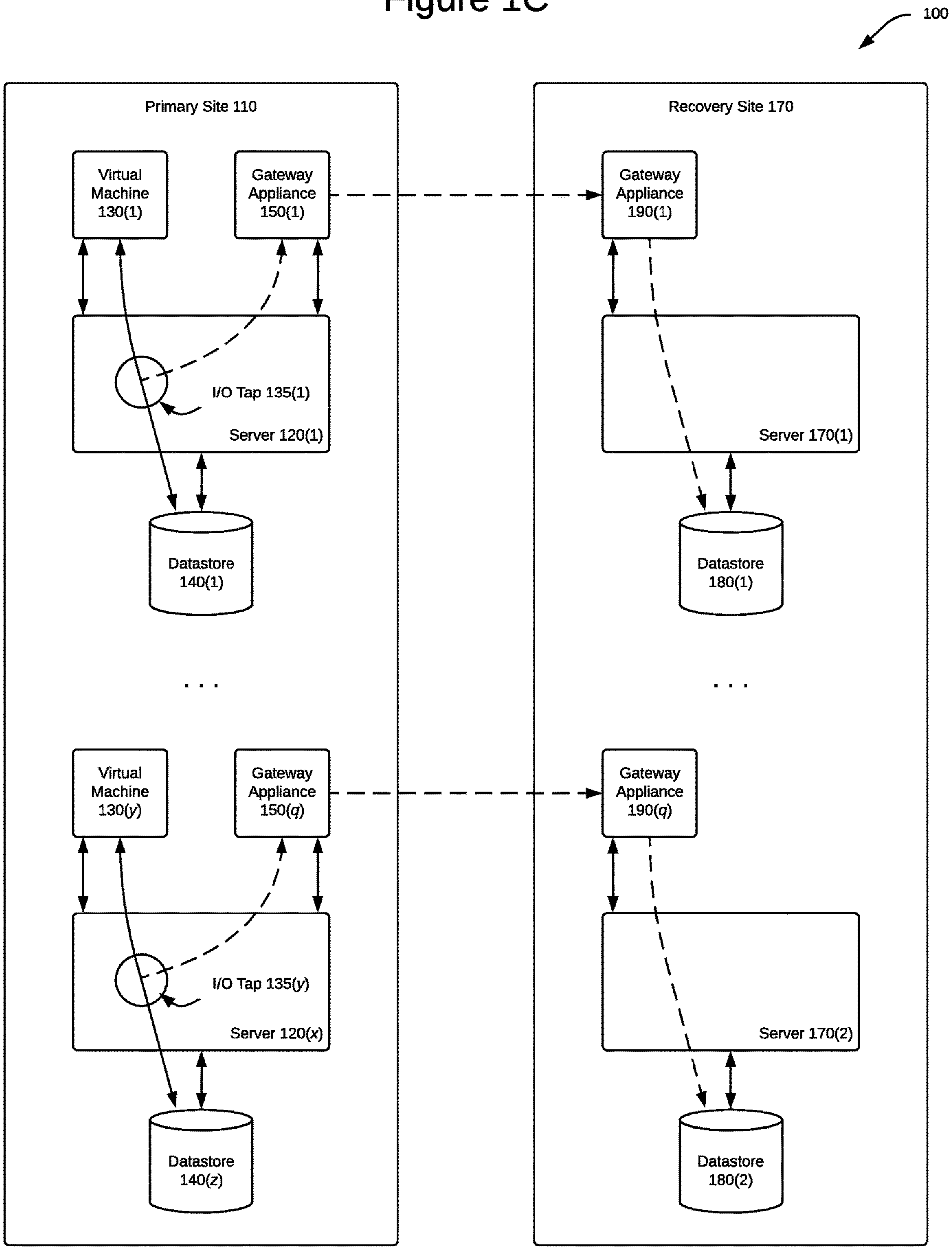

100
Primary Site 110
Virtual Machine 130(1)
Gateway Appliance 150(1)
I/O Tap 135(1)
Server 120(1)
Datastore 140(1)
. . .
Virtual Machine 130(*y*)
Gateway Appliance 150(*q*)
I/O Tap 135(*y*)
Server 120(*x*)
Datastore 140(*z*)
Recovery Site 170
Gateway Appliance 190(1)
Server 170(1)
Datastore 180(1)
. . .
Gateway Appliance 190(*q*)
Server 170(2)
Datastore 180(2)

Figure 2

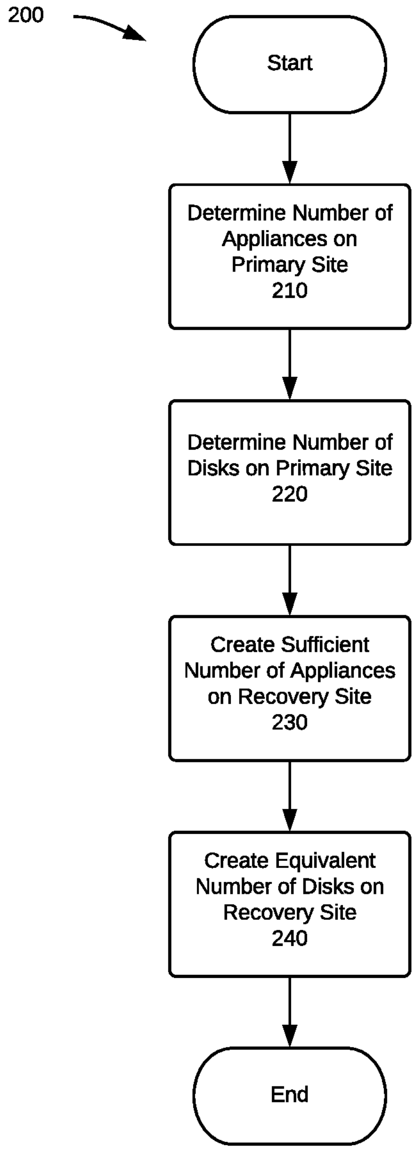

200
Start
Determine Number of Appliances on Primary Site
210
Determine Number of Disks on Primary Site
220
Create Sufficient Number of Appliances on Recovery Site
230
Create Equivalent Number of Disks on Recovery Site
240
End

Figure 3

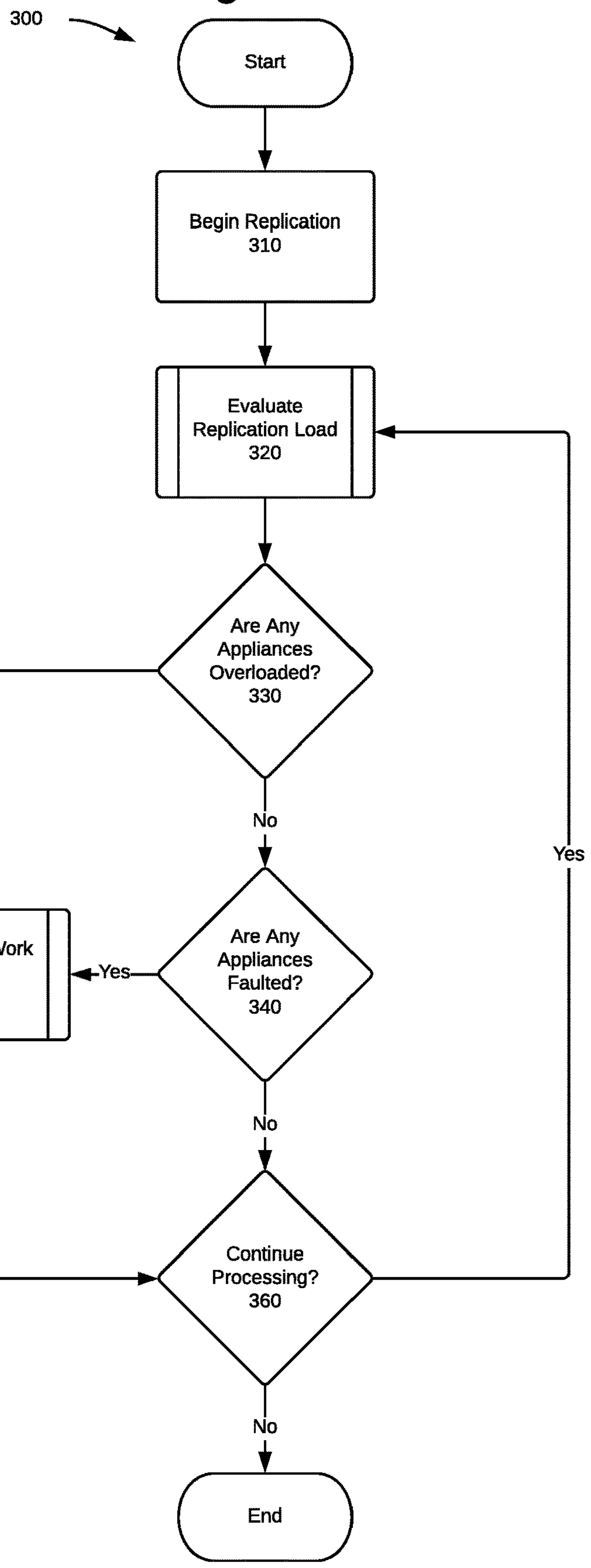

300
Start
Begin Replication
310
Evaluate
Replication Load
320
Are Any
Appliances
Overloaded?
330
Yes
No
Are Any
Appliances
Faulted?
340
Yes
Rebalance Work
Load(s)
350
No
Continue
Processing?
360
Yes
No
End

Figure 4

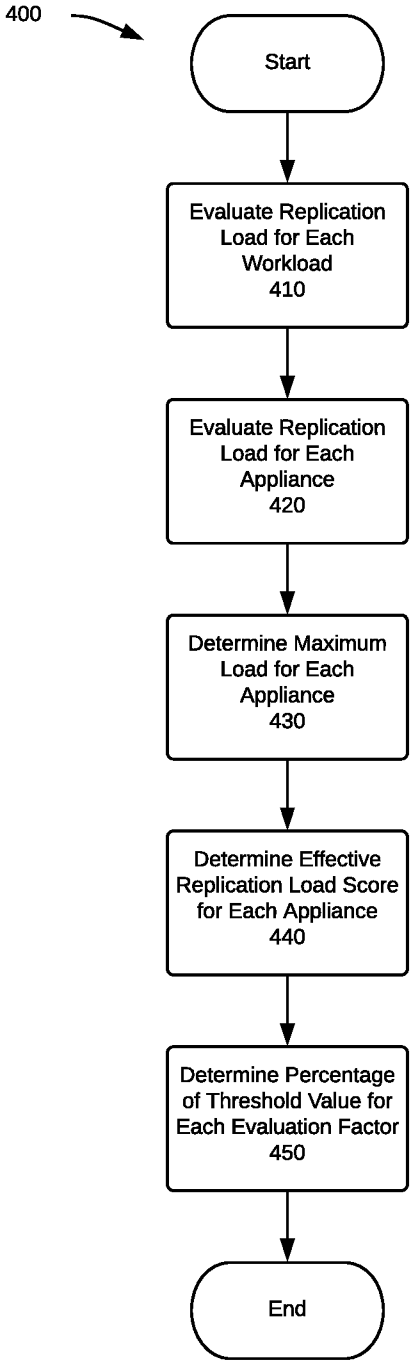

400
Start
Evaluate Replication Load for Each Workload
410
Evaluate Replication Load for Each Appliance
420
Determine Maximum Load for Each Appliance
430
Determine Effective Replication Load Score for Each Appliance
440
Determine Percentage of Threshold Value for Each Evaluation Factor
450
End

Figure 5

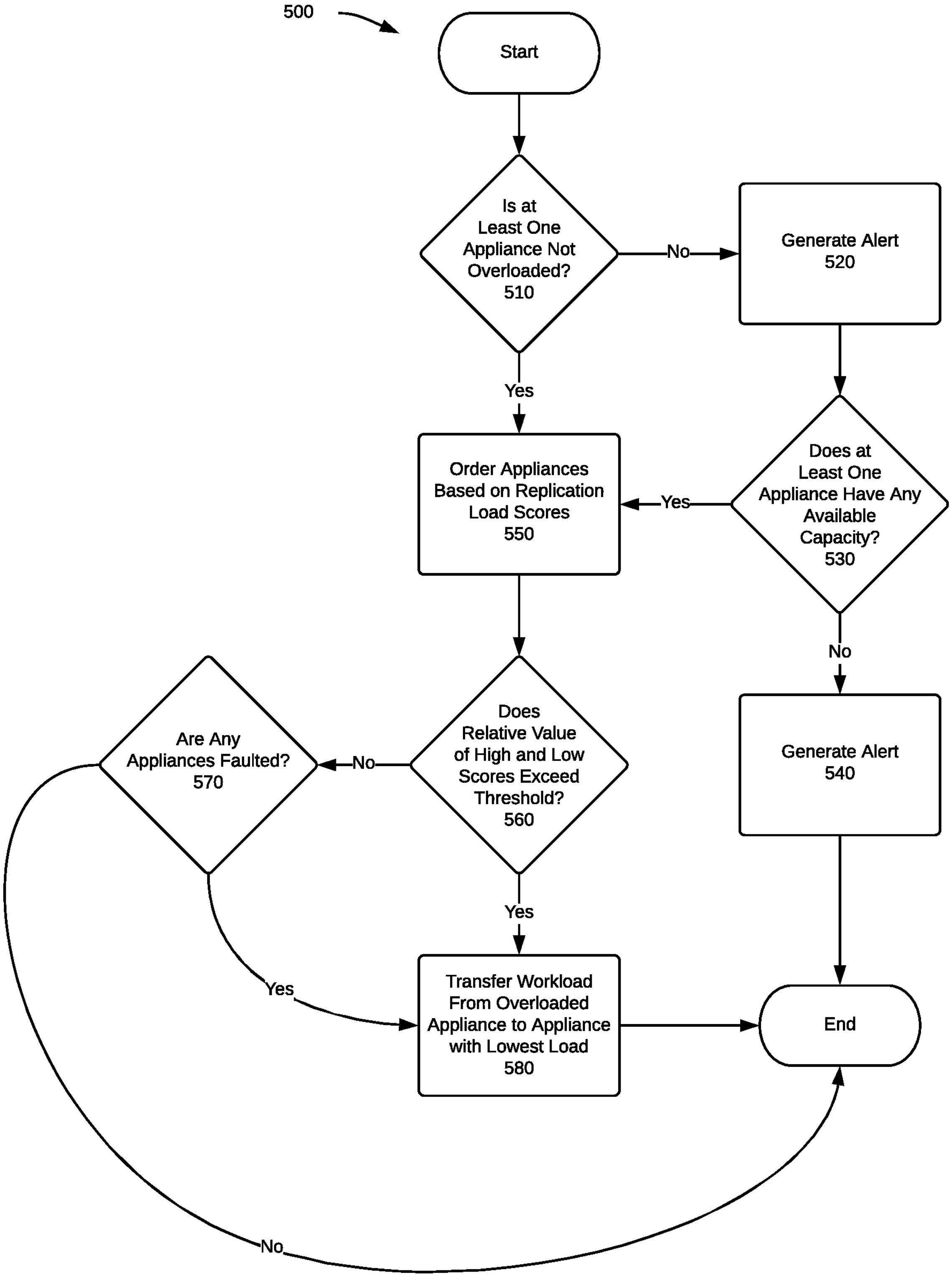
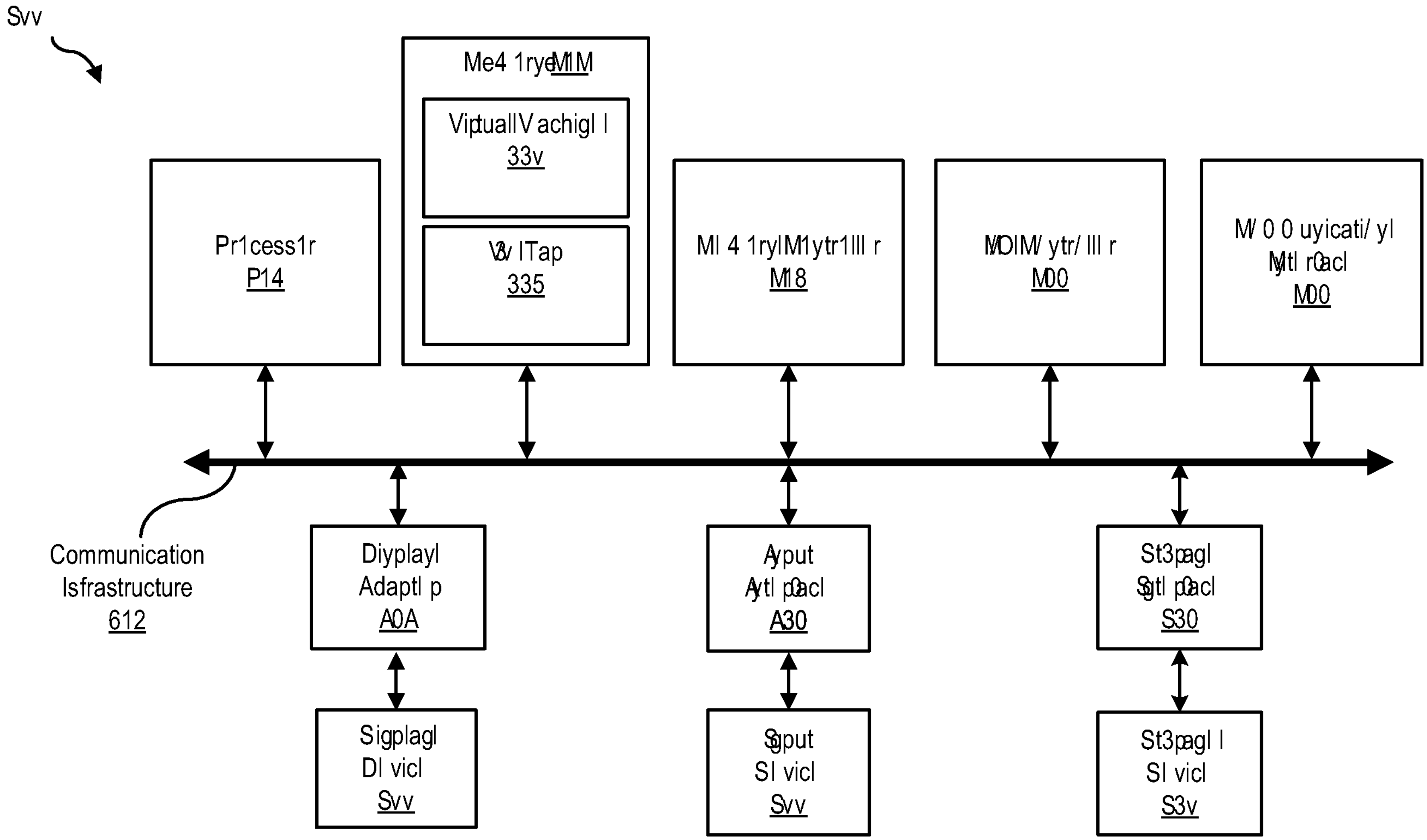

500
Start
Is at Least One Appliance Not Overloaded? 510
No
Generate Alert 520
Yes
Order Appliances Based on Replication Load Scores 550
Yes
Does at Least One Appliance Have Any Available Capacity? 530
No
Are Any Appliances Faulted? 570
No
Does Relative Value of High and Low Scores Exceed Threshold? 560
Generate Alert 540
Yes
Yes
Transfer Workload From Overloaded Appliance to Appliance with Lowest Load 580
End
No

Figure 6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Pr1cess1r
P14
Me4 1ryeM1M
VipctualI V achigl I
33v
Vv lTap
335
Ml 4 1ryIM1ytr1lll r
M18
MDIM/ ytr/ lll r
M00
M/ 0 0 uyicati/ yl
Nytl r0acl
M00
Communication
Isfrastructure
612
Diyplayl
Adaptl p
A0A
Aput
Aytl p0acl
A30
St3pagl
Sgtl p0acl
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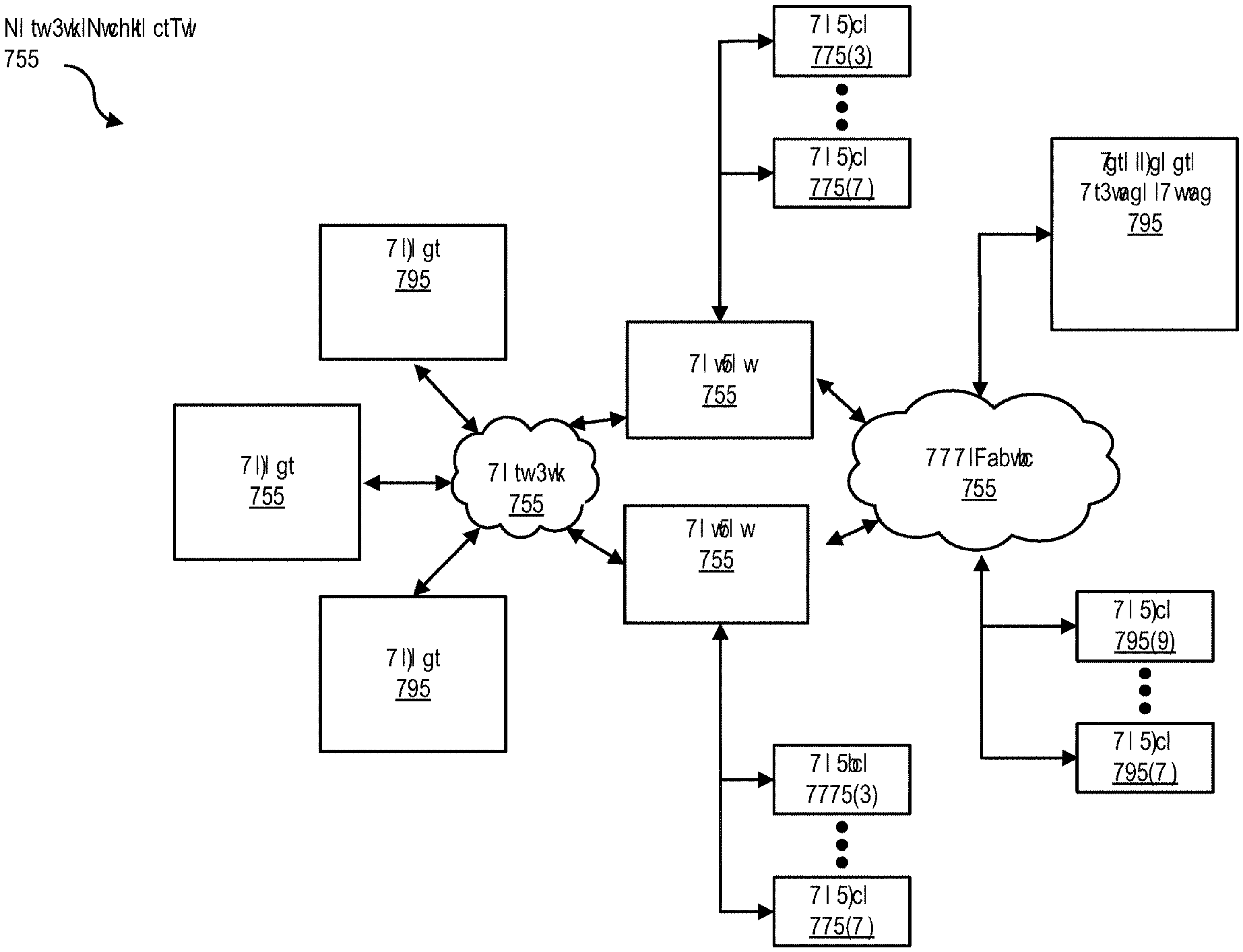
Sl vicl
S3v

Figure 7


Nl tw3vklNvchktl ctTw
755
7l)l gt
795
7l)l gt
755
7l)l gt
795
7l tw3vk
755
7l v5l w
755
7l v5l w
755
7l 5)cl
775(3)
7l 5)cl
775(7)
7l 5bcl
7775(3)
7l 5)cl
775(7)
777lFabvlc
755
7gtl ll)gl gtl
7t3vagl l7wag
795
7l 5)cl
795(9)
7l 5)cl
795(7)

INTELLIGENT AND AUTOMATIC REPLICATION LOAD SCORE BASED LOAD BALANCING AND RESILIENCY OF REPLICATION APPLIANCES

BACKGROUND OF THE INVENTION

Field of the Invention

This disclosure generally relates to the efficient replication of data among computing systems, and more specifically to automatic load balancing techniques that can be used to improve the replication of data and to provide automatic resiliency in the event of a component failure during the replication of data.

State of the Technology

Data can be replicated from a primary site to a recovery site by using virtual appliances. Such virtual appliances can be used to facilitate the replication of data that is being written by a virtual machine on the primary site. Virtual appliances on a recovery site can then be used to store the replicated data in a datastore or other location on the recovery site. However, such systems do not always scale well, and can lead to inefficiencies or data loss when problems occur within a system.

SUMMARY OF THE DISCLOSURE

The disclosure generally includes methods, computer program products, computer systems, and the like, that provide for load balancing and resiliency with respect to the replication of data between two or more computing systems, such as may occur, for example, in a cloud computing environment. In one embodiment, the functionality disclosed herein includes setting up a replication environment between a primary site and a recovery site, and beginning replication between those sites. The functionality disclosed herein can then be used to evaluate the replication load of the appliances on the replication site, and take appropriate action to dynamically rebalance the workloads of any appliances that are either overloaded or underloaded. The functionality disclosed herein can also be used to dynamically reallocate the workload of any appliance that fails or which is otherwise taken offline. The foregoing rebalancing and reallocating can be optimally and dynamically performed by evaluating various real-time and/or historical factors, such as those described in more detail herein, thereby reducing inefficiencies in the case of overloaded appliances, and eliminating the possibility of data loss when one or more appliances fail, are faulted, or are otherwise taken offline.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail, consequently those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the present disclosure, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the present application may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. **1**A is a block diagram depicting an example computing environment, and particularly an example primary site and the connections thereto, according to one embodiment of this disclosure.

FIG. **1**B is a block diagram depicting an example computing environment, and particularly an example recovery site and the connections thereto, according to one embodiment of this disclosure.

FIG. **1**C is a block diagram that provides additional details of certain components of the primary site and recovery site, according to one embodiment of this disclosure.

FIG. **2** is a flowchart depicting various actions that can be performed to set up a replication environment, according to one embodiment of this disclosure.

FIG. **3** is a flowchart depicting various actions that can be performed in relation to rebalancing the workload of virtual appliances, according to one embodiment of this disclosure.

FIG. **4** is a flowchart depicting various actions that can be performed to evaluate the replication load of virtual appliances, according to one embodiment of this disclosure.

FIG. **5** is a flowchart depicting various actions that can be performed to rebalance the work load of virtual appliances, according to one embodiment of this disclosure.

FIG. **6** is a block diagram of a computing device, illustrating how certain features of the instant disclosure can be implemented, according to one embodiment of the present disclosure.

FIG. **7** is a block diagram of a networked system, illustrating how various computing devices can communicate via a network, according to one embodiment of the present disclosure.

While the embodiments of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments are provided as examples in the drawings and detailed description. It should be understood that the drawings and detailed description are not intended to limit the embodiments to the particular form disclosed. Instead, the disclosure is intended to cover all modifications, equivalents and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

DETAILED DESCRIPTION

Data can be replicated from a primary site to a recovery site by using virtual appliances (in addition to other components, of course). Such virtual machines are used to facilitate the replication of data that is being written by a virtual machine on the primary site. This replication process includes "tapping" or otherwise intercepting data being written on the primary site, and then transmitting that data to an associated appliance on a recovery site. The appliance on the recovery site then stores the replicated data in a datastore or other location on the recovery site. The original data is stored in a separate datastore, which is part of the primary site. Moreover, each datastore can include multiple disks.

In many replication environments, however, there is an upper limit to the number of disks that can be associated with each virtual appliance. For instance, as one example, there may be a limit of 26 disks per appliance in one embodiment. In other embodiments, there can be a different maximum number of disks that can be associated with each virtual appliance. But regardless of the exact maximum number of disks that can be associated with each appliance, when the number of disks on the primary site exceeds that maximum number of disks that can be associated with each appliance, then additional appliances are needed on both sites to handle the data. For instance, if the maximum number of disks per appliance is 26, and the primary site has 52 disks, then two appliances would be needed on each site to accommodate those 52 disks. Similarly, if the maximum number of disks per appliance is 26, and the primary site has 78 disks, then three appliances would be needed on each site to accommodate those 78 disks. As such, the number of appliances that are needed to handle the disks would continue to increase as the associated systems continue to grow.

While this functionality provides some benefits, such as the ability to scale, it also creates some problems. For instance, if multiple appliances are needed in the cloud, then the workload should be balanced between those cloud appliances during the replication process. This is needed because replication will be delayed if any of the appliances become overloaded. (Of course, even a single appliance could become overloaded, but when multiple appliances are being used then it becomes possible to balance the workload between those appliances, particularly if one or more of the other appliances have extra bandwidth available.) The foregoing is true with respect to the appliances on a primary site as well as the appliances on a recovery site. That is, if multiple appliances are being used on the primary site, then the workload should be balanced between those primary site appliances during the replication process. And if multiple appliances are being used on the recovery site, then the workload should be balanced between those recovery site appliances during the replication process. However, when setting up a system such as is described herein, a user does not typically know in advance which appliances will become overloaded, or when that overloading will occur. This is due, at least in part, to the fact that the load on appliances will change and vary throughout operation. Additionally, one or more of the appliances may fail (or otherwise be disconnected, taken offline, or stop operating properly). The failure of an appliance results in downtime (at a minimum), and could even result in data loss, such as if a disaster occurs during that downtime. Obviously, a user also cannot know in advance which appliance(s) will fail, or when any such failures will occur. Thus, there exists a need to be able to dynamically and efficiently rebalance the overall workload between the remaining appliances in either of these situations, and to dynamically and efficiently provide data resiliency in the event of a failure, among other possible scenarios in which the systems and methods disclosed herein may be useful.

The disclosure generally includes methods, computer program products, computer systems, and the like, that provide for load balancing and resiliency with respect to the replication of data between two or more computing systems, such as may occur, for example, in a cloud computing environment. In one embodiment, the functionality disclosed herein includes setting up a replication environment between a primary site and a recovery site, and beginning replication between those sites. The functionality disclosed herein can then be used to evaluate the replication load of the appliances on either the primary site and/or the replication site, and take appropriate action to dynamically rebalance the workloads of any appliances that are either overloaded or underloaded. The functionality disclosed herein can also be used to dynamically reallocate the workload of any appliance that fails or which is otherwise taken offline. The foregoing rebalancing and reallocating can be optimally and dynamically performed by evaluating various real-time and/or historical factors, such as those described in more detail herein, thereby reducing inefficiencies in the case of overloaded appliances, and eliminating the possibility of data loss when one or more appliances fail, are faulted, or are otherwise taken offline. This functionally will be discussed further in conjunction with the discussion of the Figures, below.

FIG. **1**A shows an example computing environment **100** that includes a primary site and a recovery site, with a particular focus on components of primary site **110**. (The recovery site will be discussed in more detail in conjunction with FIG. **1**B, below.) In one embodiment, primary site **110** is configured as a cloud network including components such as those depicted in FIG. **1**A and discussed in more detail below. In other embodiments, primary site **110** may be configured in other ways. As can be seen in FIG. **1**A, primary site **110** includes one or more servers, such as servers **120**(**1**)-x) (collectively, “server(s) **120**”). Each server **120** can be any computer or computer system that is capable of functioning as a server, including a desktop or other stand-alone computer, a workstation, a media server, and so forth. Although not expressly shown in FIG. **1**A (or FIG. **1**B), in one embodiment, servers are communicatively coupled to each other via a cloud (or similar) computing network. As such, although each server **120** is depicted in FIG. **1**A as only being directly connected to the server(s) immediately to either side of it (for the sake of simplicity in the drawings), in practice each server may be communicatively coupled to any other server in its respective cloud. As such, each server **120** may be joined to any other server **120** via one or more connections or networks, including other servers, routers, switches, or other networking components, and so forth.

Primary site **110** also includes one or more virtual machines (“VMs”), such as virtual machines **130**(**1**)-(y) (collectively, “virtual machine(s) **130**” or “VM(s) **130**”). In one embodiment, virtual machines **130** are part of a cloud computing environment. In other embodiments, virtual machines **130** can be organized and connected in different manners. In the specific example shown in FIG. **1**A, virtual machines **130** are each hosted on one of servers **120**. In other embodiments, and regardless of the specific organizational structure of the virtual machines, each virtual machine can be hosted on other computing devices, such as a desktop or other stand-alone computer, a workstation, or any other computing device that is capable of hosting a virtual machine. Although not expressly depicted in FIG. **1**A, each server **120** typically comprises and uses a host operating system, and a hypervisor (or a virtual machine monitor or other similar software) can run on top of the host operating system. In turn, each hypervisor can host one or more of virtual machines **130**, and each instance of a virtual machine **130** executes a guest operating system. As shown in FIG. **1**A, each server **120** may host a different number of virtual machines **130** than any other server **120**. In practice, many other configurations are possible other than the specific configurations shown herein. For instance, at any given moment, each server **120** can host as few as zero virtual machines **130**, or as many virtual machines **130** as that server has the resources to operate at that time. There is no requirement that any server **120** hosts the same number of virtual machines **130** as are hosted by any other server **120**, although it is certainly possible for two or more servers **120** to host the same number of virtual machines **130** as each other at any given time.

As is also shown in FIG. **1**A, each server **120** is connected to a datastore **140**. Although depicted as a single, shared datastore in FIG. **1**A, in practice datastore **140** may include two or more distinct datastores. However, in the event that more than one datastore **140** is used in a given embodiment, each such datastore should be communicatively coupled to at least one gateway appliance, which will be discussed in more detail below. Each datastore **140** represents one or more non-transient computer readable storage mediums such as, e.g., a computer disk, flash memory, a database, or another form of computer memory (collectively, "disk(s)"). Although FIG. **1**A depicts a single datastore **140** that is connected to all of the servers **120**, in practice more than one datastore **140** can be connected to each server **120**, and more than one server **120** can be connected to each datastore **140** (if multiple datastores **140** are being used in any given embodiment).

Regardless of the specific form of storage used, each datastore **140** is capable of storing data or other information (collectively, "data") in a non-volatile manner, and is actually used in conjunction with this disclosure to store data in such a manner More specifically, datastore **140** can store one or more disks, such as disks **145**(**1**)-**145**(*z*) (collectively, "disks **145**"). Each disk **145** can take the form of a VMDK, a VHD, or any other virtual disk image file format that is supported by a given hypervisor. In one embodiment, each virtual machine **130** is associated with exactly one disk **145**, and each disk **145** is associated with exactly one virtual machine **130**. In other embodiments, each virtual machine **130** is associated with a multiple number (e.g., 2, 3, etc.) of disks **145**. Although each virtual machine **130** does not necessarily have to be associated with the same number of disks **145** as any other virtual machine **130**, each virtual machine **130** should be associated with the same number of primary site disks **145** and recovery site disks **185**, which will be discussed further below. Moreover, in addition to being used to store data, each datastore **140** can also be read by any server **120** connected to the associated datastore, such as is necessary for a server to read and retrieve data that is stored in that datastore.

Also depicted in FIG. **1**A are gateway appliances **150**(**1**)-(p) (or "appliance(s) **150**," for short). As shown in FIG. **1**A, each appliance **150** is hosted by a server **120**. As one will recognize from FIG. **1**A, however, every server **120** does not necessarily have to host an appliance **150**. For instance, in the particular embodiment shown in FIG. **1**A, servers **120**(**1**) and **120**(*x*) each host an appliance **150**, but server **120**(**2**) does not host any appliances. In other embodiments, an appliance can be hosted by a discrete machine that is communicatively coupled to other devices and components, as necessary, on primary site **110**. In practice, many other configurations are possible. For instance, in one embodiment, multiple servers **120** (and any virtual machines **130** hosted by those servers **120**) can be communicatively coupled to a single appliance **150** via a network or other connection. Moreover, although only two appliances **150** are expressly depicted in FIG. **1**A for the sake of space, in practice, more than two appliances can be used by a primary site in conjunction with this disclosure. Also, each appliance **150** is communicatively coupled to datastore **140**, and each appliance **150** is able to read and write information from and to datastore **140**, including information stored in each disk **145**.

In general, an appliance typically differs from a virtual machine in that a virtual machine will commonly be more robust, and will usually contain more functionality than is typically the case with an appliance. However, in certain embodiments, an appliance may be equivalent to or substantially equivalent to a virtual machine. In one embodiment, appliances **150** can each be a virtual machine image file consisting of a pre-configured operating system environment and a single application, as well as any functionality needed to interface with various datastores, such as datastores **140**. Appliances **150** will each typically include software that allows each appliance **150** to communicate with an associated appliance on the recovery site, such as through a network or other connection. (This will be discussed in more detail in conjunction with FIG. **1**C, below.) In certain embodiments, an appliance can also be a stand-alone computing system configured to perform operations and provide other functionality described herein. Moreover, in certain embodiments, each appliance **150** can include more, less, or different components that are expressly described here. However, regardless of the exact specifications of any given appliance, and similar to the situation with virtual machines **130**, each appliance **150** can be hosted on any computing device, such as a server, a desktop or other stand-alone computer, a workstation, a media server, or any other computing device that is capable of hosting an appliance, such as those described in more detail herein.

As can be seen in FIG. **1**A, the entire primary site **110** is either directly or indirectly connected to a network **152** via one or more connections **155**, which components in turn connect primary site **110** to recovery site **160**. Network **150** can be any sort of network, including a local area network ("LAN"), wide area network ("WAN"), storage area network ("SAN"), the Internet, an intranet, and so forth. Although only one network **150** is depicted in FIGS. **1**A and **1**B, in practice additional networks **150** can be communicatively coupled or otherwise used in conjunction with this disclosure. The reader will appreciate that, for the sake of space, only certain of the connections are specifically labeled with the number **152**, and that more or less connections may be used in any given environment. Each connection **152** can be any sort of wired and/or wireless network connection, such as an Ethernet connection, a Fiber Optic connection, a BLUETOOTH connection, and so forth, including various combinations of the foregoing technologies. Through the various connections and networks, primary site **110** (including appliances **150** and any virtual machines **130** that are being hosted on primary site **110** at any given time) is ultimately connected to recovery site **170** (including the components thereof, which will be discussed in more detail in conjunction with the discussion of FIG. **1**B, below).

FIG. **1**B shows additional details of example computing environment **100**, with a particular focus on components of recovery site **160**. (The components of primary site **110** were discussed in more detail in conjunction with FIG. **1**A, above.) In one embodiment, recovery site **160** is configured as a cloud network including components such as those depicted in FIG. **1**B and discussed in more detail below. In other embodiments, recovery site **160** may be configured in other ways. As can be seen in FIG. **1**B, recovery site **160** includes one or more servers, such as servers **170**(**1**)-(a) (collectively, "server(s) **170**"). Each server **170** can be any computer or computer system that is capable of functioning as a server, including a desktop or other stand-alone computer, a workstation, a media server, and so forth. Although not expressly shown in FIG. **1**B (or FIG. **1**A), in one embodiment, servers are communicatively coupled to each other via a cloud (or similar) computing network. As such, although each server **170** is depicted in FIG. **1**B as only being directly connected to the server(s) immediately to either side of it (for the sake of simplicity in the drawings), in practice each server may be communicatively coupled to any other server in its respective cloud. As such, each server **170** may be joined to any other server **170** via one or more connections or networks, including other servers, routers, switches, or other networking components, and so forth.

Further to the above, the reader should recognize that there is not necessarily any meaningful difference between servers **120** and servers **170**, except for the numbering provided herein. Indeed, each group of servers is labeled with distinct numbers herein in order to facilitate clarity of discussion herein, not because there is necessarily a difference between servers **120** and servers **170** in and of themselves. Of course, however, nothing in this disclosure is meant to imply that servers **120** are or must be identical to servers **170**, or even that any one of servers **120** is or must be identical to any other of servers **120** (and likewise for servers **170**).

As depicted in part by the dashed lines around virtual machines **130(1)** and **130(***y***)**, recovery site **160** is capable of hosting one or more virtual machines, but will not necessarily always do so. Rather, a virtual machine will typically only be transferred (or "failed over") to recovery site **160** if a related virtual machine **130** fails (or is otherwise taken down, disconnected from the network, and so forth) on primary site **110**. To that end, FIG. **1**B depicts virtual machines **130(1)** and **130(***y***)** as examples of virtual machines that could potentially be hosted on the servers of recovery site **160**. However, as is shown in part by the dashed borders of virtual machines **130(1)** and **130(***y***)**, these virtual machines will not necessarily always be operating on recovery site **160**, and typically will not be present when recovery site **160** is first put into operation. Moreover, in other embodiments and at other times, each server **170** may host more or less than the number of virtual machines **130** depicted with dashed borders in FIG. **1**B. Additionally, server **170(1)** can also host one or more virtual machines **130**, even though no such virtual machines are expressly depicted as being hosted by server **170(1)** in FIG. **1**B. The specifics of virtual machines **130** that can be hosted on recovery site **160** are substantially the same as the specifics of virtual **130** that are typically hosted on primary site **110**, including the connections related thereto and other components related thereto (e.g., a host operating system, a hypervisor, a guest operating system, and so forth), and therefore will not be discussed in any further detail in those regards at this point.

As is also shown in FIG. **1**B, each server **170** is connected to a datastore **180**. Although depicted as a single, shared datastore in FIG. **1**B, in practice datastore **180** may include two or more distinct datastores. However, in the event that more than one datastore **180** is used in a given embodiment, each such datastore should be communicatively coupled to at least one gateway appliance. Moreover, although FIG. **1**B depicts a single datastore **180** that is connected to all of the servers **170**, in practice more than one datastore **180** can be connected to each server **170**, and more than one server **170** can be connected to each datastore **180** (if multiple datastores **180** are being used in any given embodiment). Datastore **180** is substantially the same as datastore **140**.

Moreover, as was the case with datastore **140**, datastore **180** can store or more disks, such as disks **185(1)-185(***z***)** (collectively, "disks **185**"). Each disk **185** can take the form of a VMDK, a VHD, or any other virtual disk image file format that is supported by a given hypervisor. In one embodiment, each virtual machine **130** is associated with exactly one disk **185** on the recovery site, where that disk serves as a replica of the primary site disk **145** that is associated with the same virtual machine **130**. In other embodiments, each virtual machine **130** can associated with a multiple number (e.g., 2, 3, etc.) of disks **185**. Although each virtual machine **130** does not necessarily have to be associated with the same number of disks **185** as any other virtual machine **130**, each virtual machine **130** should be associated with the same number of primary site disks **145** and recovery site disks **185**.

As was the case with servers **120** and servers **170**, discussed above, there is not necessarily any meaningful difference between datastores **140** and datastores **180**, except for the numbering provided herein. Indeed, each group of datastores is labeled with distinct numbers herein in order to facilitate clarity of discussion herein, not because there is necessarily a difference between datastores **140** and datastores **180**. Of course, however, this also is not meant to imply that datastores **140** are or must be identical to datastores **180**, or, in the situation where more than one datastore is employed at any given time, even that any one of datastores **140** is or must be identical to any other of datastores **140** (and likewise for datastores **180**). However, there will typically be the same number z of disks **145** as there are of disks **185**. Thus, in this particular instance, and within any given implementation put into practice, z will typically have the same value with respect to disks **145** as z has with respect to disks **185**. Nevertheless, the value of z (i.e., the number of disks on each of the primary site and recovery site) can change from one implementation to the next, or even during the execution of an embodiment of this disclosure. This functionality will be explained in additional detail in conjunction with the discussion of the other figures, below.

Also depicted in FIG. **1**B are gateway appliances **190(1)**-(q) (or "appliance(s) **190**," for short). As shown in FIG. **1**B, each appliance **190** is hosted by a server **170**. Similar to the discussion of FIG. **1**A, however, every server **170** does not necessarily have to host an appliance **190**. For instance, in the particular embodiment shown in FIG. **1**B, servers **170(1)** and **170(2)** each host an appliance **190**, but server **170(***a***)** does not host any appliances. In other embodiments, an appliance can be hosted by a discrete machine that is communicatively coupled to other devices and components, as necessary, on recovery site **160**. In practice, many other configurations are possible. For instance, in one embodiment, multiple servers **170** (and any virtual machines **130** hosted by those servers **170**) can be communicatively coupled to a single appliance **190** via a network or other connection. Moreover, although only two appliances **190** are expressly depicted in FIG. **1**B for the sake of space, in practice, more than two appliances can be used by a recovery site in conjunction with this disclosure.

As was the case with other components described above, the reader should recognize that there is not necessarily any meaningful difference between appliances **150** and appliances **190**, except for the numbering provided herein. Indeed, each group of servers is labeled with distinct numbers herein in order to facilitate clarity of discussion herein, not because there is necessarily a difference between appliances **150** and appliances **190** in and of themselves. Of course, however, this also is not meant to imply that appliances **150** are or must be identical to appliances **190**, or even that any one of appliances **150** is or must be identical to any other of appliances **150** (and likewise for appliances **150**).

As used throughout this disclosure, letters such as a, p, q, x, y, and z are used to indicate a variable number of devices or components. These letters are used to indicate a variable number of instances of various devices and components, and as such, the value of each of these letter may vary from implementation to implementation of this system. However, where a given letter is used in conjunction with two different components (e.g., disks **145**(*z*) and disks **185**(*z*)), that letter should typically have the same value with respect to each of those components within a given implementation of the systems and methods described herein. Thus, for example, if z=52 in any given implementation, then the reader should understand that that implementation will include fifty-two disks **145** and fifty-two disks **185**. However, while the foregoing will typically be the case, it need not always be the case, as either the primary site or the recovery site could have more than "z" disks in any given implementation without hindering the ability to perform the methods put forth herein in conjunction with the example systems described here. Moreover, although two different variables (e.g., x and y) do not have to have the same value as each other within a given implementation, nothing in this disclosure should be read as necessarily requiring any two different variables (e.g., x and y) to have different values from each other within any given implementation, and any variable can indeed have the same value as any other variable within any given implementation.

As can be seen in FIG. **1**B, the entire recovery site **160** is either directly or indirectly connected to a network **152** via one or more connections **155**, which components in turn connects recovery site **160** to primary site **110**. Network **152** can be any sort of network, examples of which are provided above. Although only one network **152** is depicted in FIGS. **1**A and **1**B, in practice additional networks **152** can be communicatively coupled or otherwise used in conjunction with this disclosure. The reader will appreciate that, for the sake of space, only certain of the connections (examples of which are also provided above) are specifically labeled with the number **155**, and that more or less connections may be used in any given environment. Through the various connections and networks, recovery site **160** (including appliances **190** and any virtual machines **130** being hosted on recovery site **160** at any given time) is ultimately connected to primary site **110** (including appliances **150** and any virtual machines **130** being hosted on recovery site **110** at any given time), components of which were shown in more detail in FIG. **1**A.

FIG. **1**C provides enhanced details of certain components that are used to perform replication, such as the replication of step **310** below, including I/O tap operations and related components and functionality that are used to transfer data from primary site **110** to recovery site **170**. As the reader will appreciate, FIG. **1**C only depicts certain components of primary site **110** and recovery site **160**, such as are necessary for the explanation provided herewith, but does not expressly show other components that are not necessary to this portion of the explanation, including certain of the components discussed in more detail above. As the reader will appreciate, however, the "enhanced" view of the specific components provided herein does not in any way negate or eliminate or otherwise remove the other components that are discussed above with respect to primary site **110**, and recovery site **160**, respectively, including the network(s) **152** and connections **155** connecting those sites to each other.

As is shown in FIG. **1**C, virtual machine **130**(**1**) and gateway appliance **150**(**1**) are both connected to server **120**(**1**), which in turn is connected to datastore **140**, all of which can also be seen in FIG. **1**A. This group of components is then communicatively coupled with associated components on recovery site **160**, via the connection between appliance **150**(**1**) and appliance **190**(**1**). Appliance **190**(**1**) is then connected to server **170**(**1**), which in turn is connected to datastore **180**, all of which can also be seen in FIG. **1**B.

Similarly, FIG. **1**C depicts virtual machine **130**(*y*) and gateway appliance **150**(*p*), which are both connected to server **120**(*x*), which in turn is connected to datastore **140**, all of which can also be seen in FIG. **1**A. This group of components is then communicatively coupled with associated components on recovery site **160**, via the connection between appliance **150**(*p*) and appliance **190**(*q*). Appliance **190**(*q*) is then connected to server **170**(**2**), which in turn is connected to datastore **180**, all of which can also be seen in FIG. **1**B.

In practice, of course, the primary site will typically include additional servers, virtual machines, and datastores, such as those shown in FIG. **1**A; and the recovery site will typically also include at least additional servers and datastores, with the potential of hosting one or more virtual machines as required at any given time, such as is shown in FIG. **1**B.

Additionally, FIG. **1**C also shows I/O taps **135**(**1**)-(y). The reader will notice that primary site **110** includes a variable number y of virtual machines **130** and a variable number that is also y of I/O taps **135**. This is intentional, and is meant to indicate that a given primary site **110** will typically have the same number of I/O taps **135** as virtual machines **130**. This is the case because each virtual machine **130** will typically require its own I/O tap **135**, thereby resulting in a typical scenario in which there are the same number of I/O taps **135** as there are virtual machines **130**. However, this equivalence does not necessarily have to be present in every embodiment of this disclosure in order for the systems and methods described herein to operate properly. In any event, I/O taps **135** are used to intercept, or "tap," the data stream flowing from any given virtual machine to the datastore associated with that virtual machine. I/O taps **135** are typically software components, or modules, that are configured to perform the functionality required of an I/O tap in conjunction with this disclosure, and as described herein. In one embodiment, I/O taps **135** can be a VERITAS I/O TAP (VXTAPP) module. In other embodiments, other types of I/O taps can be used.

As shown by the broken lines in FIG. **1**C, as the data is read from the data stream between any given virtual machine and a datastore associated with that virtual machine, copies of (and/or other information about) the replicated data will be transmitted to the appliance most directly associated with that virtual machine. For instance, data that is being written by virtual machine **135**(**1**), and which is intercepted by I/O tap **135**(**1**), will be transmitted to appliance **150**(**1**). Similarly, data that is being written by virtual machine **135**(*y*), and which is intercepted by I/O tap **135**(*y*), will be transmitted to appliance **150**(*p*). As the reader will appreciate, more than one virtual machine, I/O tap, and/or datastore can be associated with each appliance **150**. Moreover, appliances **150** do not necessarily have to be hosted on the same server that hosts the virtual machine with which that appliance is associated. Likewise, appliances **150** do not necessarily have to be hosted on the same server to which a given datastore is connected, or upon which a given I/O tap is being executed.

In any event, once the tapped data is transmitted to the associated appliance on the primary site, that appliance will then transmit that data to the appliance on the recovery site with which the appliance on the primary site is communicatively coupled. Thus, for instance, in the example embodiment depicted in FIG. **1**C, appliance **150**(**1**) would communicate any data that it receives to appliance **190**(**1**), and appliance **150**(*p*) would communicate any data that it receives to appliance **190**(*i*). Upon receiving this data, each appliance **190** on the recovery site will in turn transmit that data to the associated datastore, as shown, for example, in FIG. **1**C, as part of the replication process of step **310**, which is discussed in more detail below. Although not expressly shown in FIG. **1**C, the receiving datastore will then write the data (or cause the data to be written) to a specific disk (such as one of disks **185**) that is associated with the virtual machine that originally generated the data that is now being written via a replication process.

Although FIG. **1**C only depicts I/O taps on two of virtual machine **130**, in practice, an I/O tap will typically be included on each virtual machine being hosted on the primary site. Each of those I/O taps will then transmit copies of (and/or other information about) the intercepted data to their associated appliance, which will then proceed to forward the data to the recovery site, such as, e.g., in the general manner described above. Moreover, although not expressly depicted in FIG. **1**C, the reader will appreciate that the data will be transmitted between each of appliances **150** and each associated appliance **190** via one or more network(s) **152** and connections **155**, such as are shown in FIGS. **1**A and **1**B. The reader will appreciate that the emphasis here is on the flow of the data from I/O taps **135** to the associated destination datastore **180** on the recovery site, not on the specific network architecture used to transmit that data, except as expressly noted in FIG. **1**C and the discussion provided herein.

FIG. **2** is a flowchart of a method **200** illustrating various actions performed in connection with one embodiment of the systems and techniques disclosed herein. As will also be appreciated in light of the present disclosure, this method may be modified in order to derive alternative embodiments. Moreover, although the steps in this embodiment are shown in a sequential order, certain steps may occur in a different order than shown, certain steps may be performed concurrently, certain steps may be combined with other steps, and certain steps may be omitted in another embodiment. Method **200** is described with reference to elements such as those described in connection with FIGS. **1**A, **1**B, and **1**C.

The general substance of method **200** was largely discussed above, in conjunction with the discussion of FIGS. **1**A, **1**B, and **1**C. Therefore, a fairly brief treatment will be given here. Nevertheless, a brief overview and discussion of the set up method should be helpful here, particularly with respect to understanding the relationship between the various components on the primary site and the various components on the recovery site. As a practitioner will recognize, many other steps are required to set up a functioning network. Method **200** should not be taken as discounting any such steps, but rather, as highlighting the specific steps that are necessary for an understanding of the other methods and functionality discussed herein.

Subject to the above, method **200** begins at **210**, where method **200** determines or is used to determine the number of appliances (such as appliances **150**) on a primary site (such as primary site **110**). Thus, in the example provided in FIGS. **1**A and **1**C, method **200** will determine that p number of appliances are present on primary site **110**. At **220**, method **200** either determines or is used to determine the number of disks on a primary site (such as primary site **110**). Thus, in the example provided in FIGS. **1**A and **1**C, method **200** will determine that z number of disks are present on primary site **110**. As indicated elsewhere herein, p and z are both whole number integers that represent variable values. Within any given implementation of the systems and methods described herein, p and z do not necessarily have to have the same value as each other, although they can. For instance, in one common embodiment, each virtual machine **130** on the primary site is associated with a specific disk **145** on the primary site, and will in turn be associated with a specific disk **185** on the recovery site, thus resulting in the same number of virtual machines **130**, disks **145**, and disks **185**. In other embodiments, each virtual machine **130** will be associated with a given multiple (e.g., 2, 3, etc.) of specific disks on the primary site, in which case each disk **145** and **185** can be viewed as representing that multiple number of disks. For instance, in one embodiment, each virtual machine **130** on the primary is associated with two specific disks **145** on the primary site, and in turn will be associated with two specific disks **185** on the recovery site. As the reader will also appreciate, steps **210** and **220** can be performed in either order, and can also be performed simultaneously or substantially simultaneously to each other.

As the reader will appreciate, step **210** is typically performed before **230**, since step **230** makes use of the information gathered in step **210** regarding the number of appliances on the primary site. However, step **220** does not necessarily have to be performed prior to step **230**. In any event, at some point after the number of appliances on the primary site is determined in **210**, method **200** will create or be used to create an equivalent number of appliances (such as appliances **190**) on a recovery site (such as recovery site **160**). Continuing with the example from above, method **200** would create or used to be create a sufficient number of appliances on the recovery site in step **230**. Thus, although there may be the same number of appliances on the primary site as there are appliances on the recovery site, in other instances a different number of appliances may be in operation on site as compared to the other.

As the reader will also appreciate, step **220** is typically performed before **240**, since step **240** makes use of the information gathered in step **220** regarding the number of disks on the primary site. However, steps **210** and **230** do not necessarily have to be performed prior to step **240**. In any event, at some point after the number of disks on the primary site is determined in **220**, method **200** will create or be used to create an equivalent number of disks on a recovery site (such as recovery site **160**). Continuing with the example from above, since method **200** would determine that there are z number of disks on the primary site in step **220**, method **200** would create or used to be create z number of disks on the recovery site in step **240**. Thus, as noted in the discussion above, there will typically be the same number z of appliances on the primary site as there are appliances on the recovery site, although this is not necessarily required.

FIG. **3** is a flowchart of a method **300** illustrating various actions performed in connection with one embodiment of the systems and techniques disclosed herein. As will also be appreciated in light of the present disclosure, this method may be modified in order to derive alternative embodiments. Moreover, although the steps in this embodiment are shown in a sequential order, certain steps may occur in a different order than shown, certain steps may be performed concurrently, certain steps may be combined with other steps, and certain steps may be omitted in another embodiment. Method **300** is described with reference to elements such as those described in connection with FIGS. **1**A, **1**B, and **1**C. In one embodiment, one or more steps of method **300** are performed by appliance(s), such as appliance(s) **150** or **190**, and/or an I/O tap module(s), such as one or more of I/O tap(s) **135**.

Prior to performing the steps of method **300**, the replication environment will typically have been set up, such as in the manner described above with respect to FIG. **2** and method **200**. Method **300** begins replication at step **310**. In one embodiment, the replication process uses an I/O tap (such as any of I/O taps **135**) to intercept data being written by a virtual machine (such as any of virtual machines **130**) to a disk (such as a disk **145**) associated with that virtual machine. In other embodiments, this data can be intercepted or otherwise captured by functionality that does not directly use an I/O tap, such as by some other module or component that is configured to intercept the data stream being written by the virtual machine, and which is also communicatively coupled to the primary site appliance which that is responsible for replicating the data being transmitted in that data stream. Typically, the process of intercepting or otherwise capturing the data being written in the data stream will produce either a copy of data and/or other information describing the data, such as metadata pertaining to that data. As used herein, the copy of the data that is read or otherwise captured, along with any metadata or other information associated with that data, will generally be referred to as "read data" or "replication data."

In any event, once the replication data is captured, such as in the manner described above, that replication data is transmitted (whether by the I/O tap, or by some other component or functionality) to the appliance (such as any of appliances **150**) that is associated with the virtual machine that was writing the original data. The appliance that receives this replication data on the primary site in turns transmits the replication data to an associated appliance on the recovery site, such as one of appliances **190**. The appliance on the recovery site that receives this replication data then writes that replication data to an associated disk (such as any of disks **185** on the recovery site) that is associated with the virtual machine that wrote the replication data. In other embodiments, the replication of step **310** may be performed in a manner different than the manner described above, and the replication process can also include more, less, and/or different components and functionality that those that have been described herein. In any event, once the replication process is started in **310**, this replication process will generally continue until the system is shut down, or until a failure occurs or until the process is otherwise interrupted for some other reason.

Moreover, the reader will note that, the replication process (and other components and functionality described herein) is/are described with respect to the normal operation of the systems and methods described herein, that is, when information is flowing primarily from production site **110** to recovery site **160**. However, as the reader will recognize, certain situations may require a component or components to be "failed over" to the recovery site, such as, e.g., when a failure occurs on the primary site server that is a hosting a given virtual machine. When such a "failover" occurs, then the flow of information will typically switch directions, as recovery site **160** would effectively become the primary site for any component that was failed over to the recovery site, and once available, the original primary site would effectively become the recovery site with respect to any component that was failed over to the recovery site. In such a situation, recovery site **160** would function as the primary site with respect to that failed over virtual machine, and primary site **110** would function as the recovery site with respect to that failed over virtual machine. (However, primary site **110** may still function as the primary site with respect to other virtual machines that have been failed over, and likewise, recovery site **160** may continue to function as the recovery site with respect to those virtual machines that have not been failed over.) Thus, with respect to any virtual machines that are failed over to the recovery site, that virtual machine would write to a datastore on recovery site **160**, the I/O tap would occur as part of that data stream, and replication would occur in the opposite direction of what is shown in FIG. **1**C. That is, the tapped data would flow from "recovery site" **160** to "primary site" **110**, and would ultimately be stored in a disk (or other portion of a datastore) on primary site **110**. However, for ease of discussion, the flow of information will be discussed with respect to the flow shown in FIG. **1**C, and thus under the assumption that the system is operating "normally," without any virtual machines having been failed over. In practice, the opposite flow is both likely and probable with respect to any given virtual machine(s). For the sake of providing a clear discussion, however, such nuances will not be noted in any significant detail, other than stating their possibility in this paragraph.

In **320**, method **300** dynamically evaluates the replication load of one or more of the appliances in real-time, e.g., while the system is already in the process of writing, reading, replicating, and storing data. Step **320** will typically evaluate the replication load of appliances on the primary site (e.g., appliances **150**) as well as appliances on the recovery site (e.g., appliances **190**). In certain embodiments, however, step **320** may only be performed at any given time with respect to the appliances on the primary site or the appliances on the recovery site, although not necessarily both groups of appliances at once. As noted above, this functionality can also be used to evaluate the replication load of appliances that are part of the primary site, generally speaking, but which are essentially being used as recovery appliances due to a previous failover of a virtual machine. In other embodiments, this step can be used to evaluate the replication work load of appliances on the primary site, even when they are functioning normally (e.g., when data is flowing in the direction shown in FIG. **1**C).

The evaluation of **320** will typically occur after replication has begun, such as, e.g., by performing step **310**. In certain embodiments, this evaluation may occur, at least in part, even prior to beginning replication, which is possible where this evaluation is based, either in whole or in part, on historical data or other predictive functionality (e.g., a general knowledge that "Black Friday" will typically generate increased traffic for an ecommerce website, even if no actual historic data exists for that site). As will be discussed in more detail below, the goal of this functionality is to ultimately determine the replication load of one or more of the appliances on the recovery site, with a particular view towards determining whether any appliances are overloaded (or are expected to become overloaded), and/or whether any appliances have access bandwidth available. The particulars of this functionality will be discussed in more detail in conjunction with FIG. **4** and method **400**, below.

After evaluating the replication load of one or more appliances, method **300** will then determine if any of the evaluated appliances are overloaded in step **330**. For instance, an appliance can be overloaded when that appliance is operating above a given acceptable threshold factor for one or more load evaluation factors. As an example, in one embodiment, the CPU usage of an appliance (either a standalone appliance, or the CPU usage of the server hosting the appliance) may be deemed unacceptable if the CPU usage crosses a given threshold level, such as, e.g., 80%. Additionally, an appliance can also be overloaded when the relative workload of that appliance exceeds the workload of another appliance (typically, another appliance on the same site, although this may not always be the case, e.g., in the case of a failover) by a certain factor, such as, e.g., **1.5**. For instance, in one embodiment, an appliance might be considered overloaded if that appliance has a workload that is at least 1.5 times the workload of another appliance. In each of the scenarios discussed earlier in this paragraph, the specific evaluation factors or parameters to be monitored can be specified and customized, e.g., such as by an end user, by a system administrator or network administrator, or even automatically during the execution of a program performing or configured to perform the functionality disclosed herein. Likewise, the acceptable values and thresholds for any such evaluation factors or parameters, as well as the acceptable relative workload of one appliance as compared to another appliance, can also be specified in such a manner and by such a person as those mentioned in the immediately preceding sentence.

If no appliances are overloaded, then method **300** will proceed to step **340**, where method **300** will determine if any appliances have faulted, in which case that appliance(s) would not be able to perform the replication activities that it would otherwise be configured to perform. A fault can occur for various reasons, such as, e.g., the appliance crashing or locking up, a network connection being disconnected or otherwise lost, or the machine upon which the appliance is hosted being powered down, among other such possibilities. If either step **330** or **340** resolve in the affirmative, then method **300** will proceed to step **350**, and rebalance the workload among two or more appliances. This functionality will be discussed in more detail below, in conjunction with the discussion of FIG. **5** and method **500**.

After completing **350**, method **300** will proceed to **360** and determine whether to continue processing. Method **300** will also proceed to step **360** if steps **330** and **340** both resolve in the negative, in which case step **350** will not be performed in that pass through method **300**. In the typical situation where **360** determines to continue processing, method **300** will then loop back to **320**, where the method will once again evaluate the replication workload of one or more appliances. Although method **300** will typically continue processing in this manner, method **300** may nevertheless be configured to briefly pause before returning to step **320**, in order to avoid unnecessarily consuming system resources or otherwise overloading the system. In other embodiments, method **300** can be configured to loop at certain time intervals, such as every one second, or every ten seconds, and so forth. While these time values are provided as examples for purposes of the discussion herein, in practice these time values can include any time value. In practice, this time value can be configured in advance, determined at run time, or hard coded into the program code, among other such possibilities. If step **360** determines that no further processing is needed, such as, e.g., if the entire system **100** is being shut down or replication site **160** is being taken offline for service, among other such possibilities, then method **300** will end.

FIG. **4** is a flowchart of a method **400** illustrating various actions performed in connection with one embodiment of the systems and techniques disclosed herein. As will also be appreciated in light of the present disclosure, this method may be modified in order to derive alternative embodiments. Moreover, although the steps in this embodiment are shown in a sequential order, certain steps may occur in a different order than shown, certain steps may be performed concurrently, certain steps may be combined with other steps, and certain steps may be omitted in another embodiment. Method **400** is described with reference to elements such as those described in connection with FIGS. **1**A, **1**B, and **1**C. In one embodiment, one or more steps of method **400** are performed by appliance(s), such as appliance(s) **150** or **190**. In one embodiment, one or more steps of method **400** are performed by an appliance configured to operate within a resiliency architecture such as that provided by VERITAS RESILENCY MANAGER. In other embodiments, one or more steps of method **400** are performed by an appliance configured to execute other replication software or functionality.

As will be discussed in more detail below, method **400** evaluates the replication load for a given workload in step **410**, and evaluates the replication load for one or more appliances in step **420**. As used herein, the term workload can be understood as the total work (e.g., replication activity) that is being performed across a given system (e.g., system **100**) for a specific customer account, although other definitions of this term are also comprehended by the scope and context of this disclosure. These evaluations (as well as the evaluations of method **500**, discussed below) are based, at least in part, on various possible "evaluation factors." These possible evaluation factors can include, but are not limited to, the number of disks that are associated with any given workload, the number of disks that are associated with each appliance, the current number of configurable replication units for any appliance, the maximum number of configurable replication units for any appliance, the size of the collective workload (across multiple potential customer accounts) for the datastores or disks, the size of the collective workload (across multiple potential customer accounts) for the appliances, the number of I/O operations ("IOPs") on the workloads, the number of IOPs on the appliances, the number of average unique blocks that are being replicated by the appliances at any given time, the maximum and current I/O operations on the replication appliances, the average or historic number of I/O operations on the appliances, the maximum and current CPU utilization on the appliances, the average or historic CPU utilization on the appliances, the maximum and current memory utilization on the appliances, the average or historic memory utilization on the appliances, the rate at which the blocks being replicated are sent from the appliance on the primary site and received at the appliance on the recovery site (e.g., the current network delay or congestion), the current recovery point objective (RPO) for a given customer (such as might be based, e.g., on a service level agreement, or "SLA"), the current recovery time objective (RTO) for a given customer (such as might be based, e.g., on an SLA), and the current lag time for any operations such as those described herein. Although numerous specific example evaluation factors are provided above, the specific evaluation factors that are used in any given embodiment can change from implementation to implementation, and any given implementation or embodiment can use any subset of these evaluation factors, and can also include other factors other than the specific evaluation factors listed above.

For each evaluation factor that is being considered in a given embodiment, each such evaluation factor will be assigned a "maximum limit" value and a weighted "load contribution factor." The maximum limit value will define a maximum acceptable level (or amount) for that evaluation factor with respect to any given appliance or workload. For instance, using one of the examples from above, the maximum limit value for CPU usage may be defined as 80% of the total available CPU availability. The weighted load contribution factor defines how much that evaluation factor will impact the actual load placed on any given appliance or workload. For instance, if a load will be increased twice as much with an increase in IOPs than by an increase of a second value, then the load contribution factor for IOPs would be 0.67 and the load contribution factor for the second value would be 0.33. This is obviously a simplified example for the sake of explanation. In practice, more factors can be considered and weighted against each other, thereby resulting in a more complex set of weights. Moreover, since the weights are relative rather than absolute, these weights can also be expressed as whole numbers (e.g., 67 and 33 in the above example) rather than decimal numbers, and can also be expressed in some other form so long as that form conveys the same general information.

Using criteria such as those provided above, method **400** can calculate a current "replication load score" for each of the customer workloads and each of the appliances, as shown in steps **410** and **420**, respectively. In one embodiment, the current replication load score for each workload or appliance can be calculated by determining the current value of each evaluation factor in use, dividing that current value by the maximum limit value for that evaluation factor to produce a "usage quotient," and then applying the load contribution factor for that evaluation factor to weigh that usage quotient appropriately. In other embodiments, an average value (such as, e.g., the average historical value over a certain time period) can be used instead of the current value. Other calculation methods are possible as well. Regardless of the specific calculation method and values used, this process would be repeated for each evaluation factor being used, with the results of each individual calculation being added together to produce an overall current replication load score summary value for the workload or appliance being evaluated.

In addition to evaluating the current replication load for the workloads and appliances (such as, e.g., in the manner discussed above), method **400** can also determine the maximum replication load that each appliance can handle, in step **430**. This maximum value can be determined by, e.g., evaluating the predetermined specifications for any given device or appliance. For instance, a given appliance may be known to be able to perform a certain number of IOPs per second, or to have a certain maximum CPU capacity. This information may be provided by a manufacturer, or may be obtained by other means. In one embodiment, the maximum replication load can be determined by calculating a maximum replication load score. This maximum replication load score can be calculated by determining the maximum value of each evaluation factor in use, dividing that current value by the maximum limit value for that evaluation factor to produce a "usage quotient" for that factor, and then applying the load contribution factor for that evaluation factor to weigh that usage quotient appropriately. As was the case for the current replication load score calculated above, this process would be repeated for each evaluation factor being used, with the results of each individual calculation being added together to produce an overall maximum replication load score for the workload or appliance being evaluated.

In **440**, method **400** determines an effective replication load score for each appliance. In one embodiment, the effective replication load score can be determined by calculating a quotient or ratio by dividing the current replication load score summary value for each appliance (step **420**) by the maximum replication load score for that appliance (step **430**).

Finally, in **450**, method **400** can determine a current threshold percentage value for each evaluation criteria being considered with respect to each appliance. For instance, for each evaluation factor on each appliance, the current threshold percentage value can be determined by dividing the average value for that evaluation factor by the maximum value for that factor, where the average and maximum values are determined in a manner such as those described above. This value can be expressed as a decimal factor (e.g., 0.67), as a percentage (e.g., 67%), or in some other suitable manner.

FIG. **5** is a flowchart of a method **500** illustrating various actions performed in connection with one embodiment of the systems and techniques disclosed herein. As will also be appreciated in light of the present disclosure, this method may be modified in order to derive alternative embodiments. Moreover, although the steps in this embodiment are shown in a sequential order, certain steps may occur in a different order than shown, certain steps may be performed concurrently, certain steps may be combined with other steps, and certain steps may be omitted in another embodiment. Method **500** is described with reference to elements such as those described in connection with FIGS. **1**A, **1**B, and **1**C. In one embodiment, one or more steps of method **500** are performed by appliance(s), such as appliance(s) **150** or **190**. In one embodiment, one or more steps of method **500** are performed by an appliance configured to operate within a resiliency architecture such as that provided by VERITAS RESILENCY MANAGER. In other embodiments, one or more steps of method **500** are performed by an appliance configured to execute other replication software or functionality.

Method **500** begins at **510**, where the method determines whether at least one appliance is not currently overloaded. If **510** determines that there are not any appliances that are not currently overloaded (e.g., all appliances are currently overloaded), method **500** then proceeds to **520** and issues an alert. This alert can take various forms, such as an email, automated text message, or computer dialog box such as in a WINDOWS computing environment. In one embodiment, this alert will be directed to a customer and will include information indicating that all of the appliances on their recovery site are currently overloaded. A user can then respond to this information in various ways, such as by adding a new appliance or taking other measures, which are beyond the scope of this disclosure. If step **520** was reached (e.g., if method **500** determined that all of the appliances were currently overloaded), method **500** then proceeds to **520** to determine if any of those appliances, even though overloaded, nevertheless have any remaining capacity available. For instance, an appliance operating at 85% of its CPU threshold may be overloaded (if the threshold limit was set to 80%, per the example used above) but may nevertheless have some capacity remaining (since 85% is still less than 100%). If this determination also evaluates in the negative (e.g., none of the appliances have any capacity remaining), then the system is overloaded and fairly drastic measures (albeit measures which are beyond the scope of this disclosure) are necessary. At this point, a second alert is generated in **540** (or a single alert is generated here, in place of the alert from **520**). This alert may be similar to the alert described with respect to **520**, except that the content of the alert should reflect the fact that none of the appliances have any capacity remaining. At this point, method **500** would end.

However, if either step **510** or step **530** evaluate in the affirmative (e.g., at least one device is not overloaded, per **510**; or at least one device has some capacity remaining, per

530), method **500** proceeds to **550**. In **550**, the appliances are sorted or otherwise ordered based on their effective replication load score, such as was determined in **440**. At this point, although not expressly shown in FIG. **5**, method **500** can also identify the appliance with the highest load and the appliance with the lowest load, as well as their respective effective replication load scores. At **560**, method **500** can determine whether the relative difference between the highest load score and the lowest load score exceeds a relative load difference threshold, such as, e.g., determining whether the highest score is at least 1.5 times as high as the lowest score. If this determination evaluates in the positive, then at least one appliance is overloaded with respect to the workload of at least one other appliance. If **560** evaluates in the negative, then method **500** determines if any appliances have been faulted in **570**, in which case the workload should be rebalanced (or at least attempted to be rebalanced), even if none of the other appliances are overloaded, since at least one of the appliances is now offline and that appliance's workload should be performed by some other appliance. In practice, although multiple steps of this method can be performed in different orders than what is expressly shown in FIG. **5**, the reader will recognize that steps **560** and **570** in particular can be performed in the opposite order of what is shown, and can also be performed at the same time or substantially the same time as each other. In any event, if both of these steps evaluate in the negative, then method **500** will end. However, if either of these steps evaluate in the positive, then method **500** will proceed to **580**.

At **580**, method **500** rebalances the various workloads by shifting a portion of the workload from one or more appliances that are overloaded, to one or more appliances on the same site (or functioning as part of the same site) that have a lower replication load score (or otherwise have available capacity). If additional unused appliances are available with respect to that site, one or more unused appliance may also be brought on line at this point, particularly (but not only) in the situation where one or more of the previously-used appliances has failed or has otherwise been taken offline. In one embodiment, method **500** can be used to determine how much of the workload should be shifted from the overloaded (or faulted) appliance(s) to other appliances that have available capacity, in order to even out (or roughly even out) the workload distribution among the appliances on that site (or among the appliances operating as part of the same site). For instance, method **500** may determine the difference in workload between the most overloaded appliance and the most underloaded appliance, and then shift one-half (or some other portion) of that workload from the most overloaded appliance to the most underloaded appliance. Method **500** then either ends, or although not expressly shown in FIG. **5**, method **500** can also repeat this same basic functionality for other appliances, until the various workloads have been generally evened out and the workload of all faulted appliances have been redistributed to other online appliances.

FIG. **6** is a block diagram of a computing system **600** capable of performing one or more of the operations described above. Computing system **600** broadly represents any single or multi-processor computing device or system capable of executing computer-readable instructions. Examples of computing system **600** include, without limitation, any one or more of a variety of devices including workstations, personal computers, laptops, client-side terminals, servers, distributed computing systems, handheld devices (e.g., personal digital assistants and mobile phones), network appliances, storage controllers (e.g., array controllers, tape drive controller, or hard drive controller), and the like. In its most basic configuration, computing system **600** may include at least one processor **614** and a memory **616**. By executing software that invokes, e.g., a virtual machine **130** and/or an I/O tap **135**, or that causes the computing device to function as an appliance such as appliances **150** or **190**, or any modifications thereof consistent with this disclosure, computing system **600** becomes a special purpose computing device that is configured to perform operations in the manner described above.

Processor **614** generally represents any type or form of processing unit capable of processing data or interpreting and executing instructions. In certain embodiments, processor **614** may receive instructions from a software application or module. These instructions may cause processor **614** to perform the functions of one or more of the embodiments described and/or illustrated herein. For example, processor **614** may perform and/or be a means for performing the operations described herein. Processor **614** may also perform and/or be a means for performing any other operations, methods, or processes described and/or illustrated herein.

Memory **616** generally represents any type or form of volatile or non-volatile storage devices or mediums capable of storing data and/or other computer-readable instructions. Examples include, without limitation, random access memory (RAM), read only memory (ROM), flash memory, a hard disk drive, or any other suitable memory device. Although not required, in certain embodiments computing system **600** may include both a volatile memory unit and a non-volatile storage device. In one example, program instructions implementing on or more operations described herein may be loaded into memory **610**.

In certain embodiments, computing system **600** may also include one or more components or elements in addition to processor **614** and memory **616**. For example, as illustrated in FIG. **6**, computing system **600** may include a memory controller **618**, an Input/Output (I/O) controller **620**, and a communication interface **622**, each of which may be interconnected via a communication infrastructure **612**. Communication infrastructure **612** generally represents any type or form of infrastructure capable of facilitating communication between one or more components of a computing device. Examples of communication infrastructure **612** include, without limitation, a communication bus (such as an Industry Standard Architecture (ISA), Peripheral Component Interconnect (PCI), PCI express (PCIe), or similar bus) and a network.

Memory controller **618** generally represents any type or form of device capable of handling memory or data or controlling communication between one or more components of computing system **600**. For example, in certain embodiments memory controller **618** may control communication between processor **614**, memory **616**, and I/O controller **620** via communication infrastructure **612**. In certain embodiments, memory controller **618** may perform and/or be a means for performing, either alone or in combination with other elements, one or more of the operations or features described and/or illustrated herein.

I/O controller **620** generally represents any type or form of module capable of coordinating and/or controlling the input and output functions of a computing device. For example, in certain embodiments I/O controller **620** may control or facilitate transfer of data between one or more elements of computing system **600**, such as processor **614**, memory **616**, communication interface **622**, display adapter **626**, input interface **630**, and storage interface **634**.

Communication interface **622** broadly represents any type or form of communication device or adapter capable of facilitating communication between computing system **600** and one or more additional devices. For example, in certain embodiments communication interface **622** may facilitate communication between computing system **600** and a private or public network including additional computing systems. Examples of communication interface **622** include, without limitation, a wired network interface (such as a network interface card), a wireless network interface (such as a wireless network interface card), a modem, and any other suitable interface. In at least one embodiment, communication interface **622** may provide a direct connection to a remote server via a direct link to a network, such as the Internet. Communication interface **622** may also indirectly provide such a connection through, for example, a local area network (such as an Ethernet network), a personal area network, a telephone or cable network, a cellular telephone connection, a satellite data connection, or any other suitable connection.

In certain embodiments, communication interface **622** may also represent a host adapter configured to facilitate communication between computing system **600** and one or more additional network or storage devices via an external bus or communications channel. Examples of host adapters include, without limitation, Small Computer System Interface (SCSI) host adapters, Universal Serial Bus (USB) host adapters, Institute of Electrical and Electronics Engineers (IEEE) 1894 host adapters, Serial Advanced Technology Attachment (SATA) and external SATA (eSATA) host adapters, Advanced Technology Attachment (ATA) and Parallel ATA (PATA) host adapters, Fibre Channel interface adapters, Ethernet adapters, or the like.

Communication interface **622** may also allow computing system **600** to engage in distributed or remote computing. For example, communication interface **622** may receive instructions from a remote device or send instructions to a remote device for execution.

As illustrated in FIG. **6**, computing system **600** may also include at least one display device **624** coupled to communication infrastructure **612** via a display adapter **626**. Display device **624** generally represents any type or form of device capable of visually displaying information forwarded by display adapter **626**. Similarly, display adapter **626** generally represents any type or form of device configured to forward graphics, text, and other data from communication infrastructure **612** (or from a frame buffer) for display on display device **624**.

As illustrated in FIG. **6**, computing system **600** may also include at least one input device **628** coupled to communication infrastructure **612** via an input interface **630**. Input device **628** generally represents any type or form of input device capable of providing input, either computer or human generated, to computing system **600**. Examples of input device **628** include, without limitation, a keyboard, a pointing device, a speech recognition device, or any other input device.

As illustrated in FIG. **6**, computing system **600** may also include a storage device **632** coupled to communication infrastructure **612** via a storage interface **634**. Storage device **632** generally represents any type or form of storage device or medium capable of storing data and/or other computer-readable instructions. For example, storage device **632** may be a magnetic disk drive (e.g., a so-called hard drive), a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash drive, or the like. Storage interface **634** generally represents any type or form of interface or device for transferring data between storage device **632** and other components of computing system **600**. A storage device like storage device **632** can store information such as the data structures described herein, as well as one or more computer-readable programming instructions that are capable of causing a computer system to execute one or more of the operations described herein.

In certain embodiments, storage device **632** may be configured to read from and/or write to a removable storage unit configured to store computer software, data, or other computer-readable information. Examples of suitable removable storage units include, without limitation, a floppy disk, a magnetic tape, an optical disk, a flash memory device, or the like. Storage device **632** may also include other similar structures or devices for allowing computer software, data, or other computer-readable instructions to be loaded into computing system **600**. For example, storage device **632** may be configured to read and write software, data, or other computer-readable information. Storage devices **632** may also be a part of computing system **600** or may be a separate device accessed through other interface systems.

Many other devices or subsystems may be connected to computing system **600**. Conversely, all of the components and devices illustrated in FIG. **6** need not be present to practice the embodiments described and/or illustrated herein. The devices and subsystems referenced above may also be interconnected in different ways from that shown in FIG. **6**.

Computing system **600** may also employ any number of software, firmware, and/or hardware configurations. For example, one or more of the embodiments disclosed herein may be encoded as a computer program (also referred to as computer software, software applications, computer-readable instructions, or computer control logic) on a non-transient computer-readable storage medium. Examples of non-transient computer-readable storage media include magnetic-storage media (e.g., hard disk drives and floppy disks), optical-storage media (e.g., CD- or DVD-ROMs), electronic-storage media (e.g., solid-state drives and flash media), and the like. Such computer programs can also be transferred to computing system **600** for storage in memory via a network such as the Internet or upon a carrier medium.

The non-transient computer-readable storage medium containing the computer programming instructions may be loaded into computing system **600**. All or a portion of the computer programming instructions stored on the non-transient computer-readable storage medium may then be stored in memory **616** and/or various portions of storage device **632**. When executed by processor **614**, a computer program loaded into computing system **600** may cause processor **614** to perform and/or be a means for performing the functions of one or more of the embodiments described and/or illustrated herein. Additionally or alternatively, one or more of the embodiments described and/or illustrated herein may be implemented in firmware and/or hardware. For example, computing system **600** may be configured as an application specific integrated circuit (ASIC) adapted to implement one or more of the embodiments disclosed herein.

FIG. **7** is a block diagram of a network architecture **700** in which client systems **710**, **720**, and **730**, and servers **740** and **745** may be coupled to a network **750**. Client systems **710**, **720**, and **730** generally represent any type or form of computing device or system, such as computing system **600** in FIG. **6**.

Similarly, servers **740** and **745** generally represent computing devices or systems, such as application servers or database servers, configured to provide various database services and/or run certain software applications. Network

750 generally represents any telecommunication or computer network including, for example, an intranet, a wide area network (WAN), a local area network (LAN), a personal area network (PAN), or the Internet. In one example, one or more of client systems **710**, **720**, and/or **730** may include software configured to execute, e.g., a virtual machine **130** and/or an I/O tap **135**, or that causes the computing device to function as an appliance such as appliances **150** or **190**, and/or one or more components or threads thereof.

As illustrated in FIG. **7**, one or more storage devices **760**(**1**)-(N) may be directly attached to server **740**. Similarly, one or more storage devices **770**(**1**)-(N) may be directly attached to server **745**. Storage devices **760**(**1**)-(N) and storage devices **770**(**1**)-(N) generally represent any type or form of storage device or medium capable of storing data and/or other computer-readable instructions. In certain embodiments, storage devices **760**(**1**)-(N) and storage devices **770**(**1**)-(N) may represent network-attached storage (NAS) devices configured to communicate with servers **740** and **745** using various protocols, such as Network File System (NFS), Server Message Block (SMB), or Common Internet File System (CIFS). Such storage devices can store backup information and storage configuration information, as described above.

Servers **740** and **745** may also be connected to a storage area network (SAN) fabric **780**. SAN fabric **780** generally represents any type or form of computer network or architecture capable of facilitating communication between multiple storage devices. SAN fabric **780** may facilitate communication between servers **740** and **745** and a plurality of storage devices **790**(**1**)-(N) and/or an intelligent storage array **795**. SAN fabric **780** may also facilitate, via network **750** and servers **740** and **745**, communication between client systems **710**, **720**, and **730** and storage devices **790**(**1**)-(N) and/or intelligent storage array **795** in such a manner that devices **790**(**1**)-(N) and array **795** appear as locally attached devices to client systems **710**, **720**, and **730**. As with storage devices **760**(**1**)-(N) and storage devices **770**(**1**)-(N), storage devices **790**(**1**)-(N) and intelligent storage array **795** generally represent any type or form of storage device or medium capable of storing data and/or other computer-readable instructions.

In certain embodiments, and with reference to computing system **600** of FIG. **6**, a communication interface, such as communication interface **622** in FIG. **6**, may be used to provide connectivity between each client system **710**, **720**, and **730** and network **750**. Client systems **710**, **720**, and **730** may be able to access information on server **740** or **745** using, for example, a web browser or other client software. Such software may allow client systems **710**, **720**, and **730** to access data hosted by server **740**, server **745**, storage devices **760**(**1**)-(N), storage devices **770**(**1**)-(N), storage devices **790**(**1**)-(N), or intelligent storage array **795**. Although FIG. **7** depicts the use of a network (such as the Internet) for exchanging data, the embodiments described and/or illustrated herein are not limited to the Internet or any particular network-based environment.

In at least one embodiment, all or a portion of one or more of the embodiments disclosed herein may be encoded as a computer program and loaded onto and executed by server **740**, server **745**, storage devices **740**(**1**)-(N), storage devices **770**(**1**)-(N), storage devices **790**(**1**)-(N), intelligent storage array **795**, or any combination thereof. All or a portion of one or more of the embodiments disclosed herein may also be encoded as a computer program, stored in server **740**, run by server **745**, and distributed to client systems **710**, **720**, and **730** over network **750**.

In some examples, all or a portion of one of the systems in FIGS. **1**A, **1**B, **1**C, **6**, and **7** may represent portions of a cloud-computing or network-based environment. Cloud-computing environments may provide various services and applications via the Internet. These cloud-based services (e.g., software as a service, platform as a service, infrastructure as a service, etc.) may be accessible through a web browser or other remote interface. Various functions described herein may be provided through a remote desktop environment or any other cloud-based computing environment.

In addition, one or more of the components described herein may transform data, physical devices, and/or representations of physical devices from one form to another. For example, one or more of the operations described herein may transform the behavior of a computer system such that the various operations described herein can be performed.

Although the present invention has been described in connection with several embodiments, the invention is not intended to be limited to the specific forms set forth herein. On the contrary, it is intended to cover such alternatives, modifications, and equivalents as can be reasonably included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A method comprising:

initiating a replication process between a primary site and a recovery site, wherein

the recovery site comprises at least a first gateway appliance and a second gateway appliance;

evaluating a replication load for the first gateway appliance, wherein

the evaluating the replication load for the first gateway appliance comprises analyzing at least a first evaluation factor for the first gateway appliance and a second evaluation factor for the first gateway appliance, and

the first evaluation factor for the first gateway appliance and the second evaluation factor for the first gateway appliance are both related to the replication load of the replication process on the first gateway appliance, wherein

a first weight is applied to the first evaluation factor of the first gateway appliance, and

a second weight is applied to the second evaluation factor of the first gateway appliance, wherein the first weight of the first evaluation factor of the first gateway appliance is greater than the second weight of the second evaluation factor of the gateway appliance;

evaluating a replication load for the second gateway appliance, wherein

the evaluating the replication load of the second gateway appliance includes analyzing at least a first evaluation factor for the second gateway appliance and a second evaluation factor for the second gateway appliance;

the first evaluation factor for the second gateway appliance and the second evaluation factor for the second gateway appliance are both related to the replication load of the replication process on the second gateway appliance;

determining whether the first gateway appliance is overloaded based on the replication load of the replication process on the first gateway appliance; and

in response to determining that the first gateway appliance is overloaded, rebalancing a replication workload between the first gateway appliance and the second gateway appliance based on the replication load on the first gateway appliance and the replication load on the second gateway appliance.

2. The method of claim **1**, wherein

the first evaluation factor pertains to a current replication lag time associated with the first gateway appliance.

3. The method of claim **1**, wherein

the first evaluation factor is evaluated based on historic data pertaining to memory utilization of one or more appliances on the recovery site.

4. The method of claim **1**, wherein

the second evaluation factor pertains to a number of average unique blocks of data directed to the first appliance.

5. The method of claim **1**, wherein

the determining whether the first gateway appliance is overloaded comprises comparing the replication load on the first gateway appliance to the replication load on the second gateway appliance.

6. The method of claim **1**, wherein

initiating the replication process further comprises executing an I/O tap with respect to data being written from a first virtual machine to a first disk, wherein

the primary site comprises the first virtual machine and the first disk.

7. A system comprising:

a microprocessor; and

a non-transient computer-readable storage medium, comprising computer instructions executable by the microprocessor, wherein the computer instructions are configured to perform a method comprising the steps of:

receiving replication data, wherein

the replication data is received at a recovery site from a replication process initiated on a primary site, and

the recovery site comprises at least a first gateway appliance and a second gateway appliance;

evaluating a replication load for the first gateway appliance, wherein

the evaluating the replication load comprises analyzing at least a first evaluation factor for the first gateway appliance and a second evaluation factor for the first gateway appliance, and

the first evaluation factor for the first gateway appliance and the second evaluation factor for the first gateway appliance are both related to the replication load of the replication process on the first gateway appliance, wherein

a first weight is applied to the first evaluation factor of the first gateway appliance, and

a second weight is applied to the second evaluation factor of the first gateway appliance, wherein the first weight of the first evaluation factor of the first gateway appliance is greater than the second weight of the second evaluation factor of the gateway appliance;

evaluating a replication load for the second gateway appliance, wherein

the evaluating the replication load comprises analyzing at least a first evaluation factor for the second getaway appliance and a second evaluation factor for the second gateway appliance, and

the first evaluation factor for the second gateway appliance and the second evaluation factor for the second gateway appliance are both related to the replication load of the replication process on the second gateway appliance;

determining whether the first gateway appliance is overloaded based on the replication load of the replication process on the first gateway appliance; and

in response to determining that the first gateway appliance is overloaded, rebalancing a replication workload between the first gateway appliance and the second gateway appliance based on the replication load on the first gateway appliance and the replication load on the second gateway appliance.

8. The method of claim **7**, wherein

the first evaluation factor pertains to a current replication lag time associated with the first appliance.

9. The method of claim **7**, wherein

the first evaluation factor is evaluated based on historic data pertaining to memory utilization of one or more appliances on the recovery site.

10. The method of claim **7**, wherein

the second evaluation factor pertains to a number of average unique blocks of data directed to the first appliance.

11. The method of claim **7**, wherein

the determining whether the first gateway appliance is overloaded comprises comparing the replication load on the first gateway appliance to the replication load on the second gateway appliance.

12. The method of claim **7**, wherein

the replication process further comprises executing an I/O tap with respect to data being written from a first virtual machine to a first disk, wherein the primary site comprises the first virtual machine and the first disk.

13. A computer program product, comprising a plurality of instructions stored on a non-transient computer-readable storage medium, wherein the instructions are configured to execute a method comprising the steps of:

receiving replication data, wherein

the replication data is received at a recovery site from a replication process initiated on a primary site, and

the recovery site comprises at least a first gateway appliance and a second gateway appliance;

evaluating a replication load for the first gateway appliance, wherein

the evaluating the replication load comprises analyzing at least a first evaluation factor for the first gateway appliance and a second evaluation factor for the first gateway appliance, and

the first evaluation factor for the first gateway appliance and the second evaluation factor for the first gateway appliance are both related to the replication load of the replication process on the first gateway appliance,

wherein

a first weight is applied to the first evaluation factor of the first gateway appliance, and

a second weight is applied to the second evaluation factor of the first gateway appliance, wherein the first weight of the first evaluation factor of the first gateway appliance is greater than the second weight of the second evaluation factor of the gateway appliance;

evaluating a replication load of the second gateway appliance, wherein the evaluating of the replication load on the second gateway appliance comprises analyzing at least a first evaluation factor for the second getaway appliance and a second evaluation factor for the second gateway appliance, and

the first evaluation factor for the second gateway appliance and the second evaluation factor for the second gateway appliance are both related to the replication load of the replication process on the second gateway appliance;

determining whether the first gateway appliance is overloaded based on the replication load of the replication process on the first gateway appliance; and

in response to determining that the first gateway appliance is overloaded, rebalancing a replication workload between the first gateway appliance and the second gateway appliance based on the replication load on the first gateway appliance and the replication load on the second gateway appliance.

14. The method of claim **13**, wherein

the first evaluation factor pertains to a current replication lag time associated with the first appliance.

15. The method of claim **13**, wherein

the first evaluation factor is evaluated based on historic data pertaining to memory utilization of one or more appliances on the recovery site.

16. The method of claim **13**, wherein

the second evaluation factor pertains to a number of average unique blocks of data directed to the first appliance.

17. The method of claim **13**, wherein

the determining whether the first gateway appliance is overloaded comprises comparing the replication load on the first gateway appliance to the replication load on the second gateway appliance.

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